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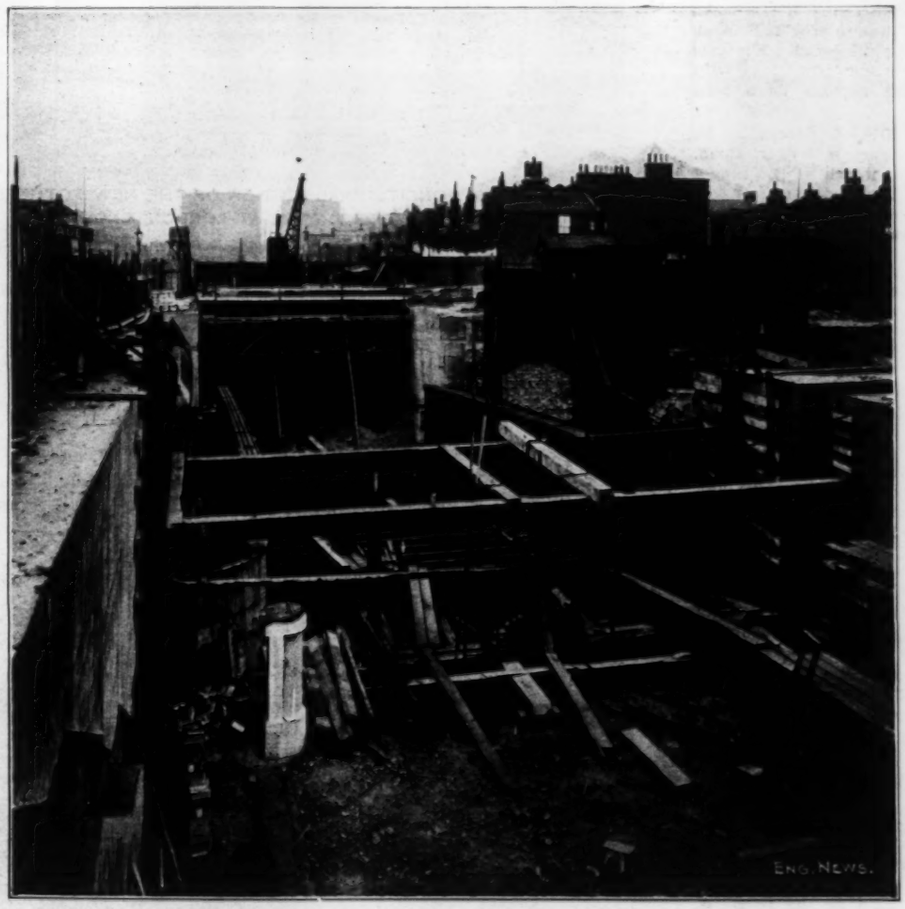
A NEW HIGHWAY TUNNEL UNDER THE THAMES RIVER AT LONDON, ENGLAND.

By E. H. TABOR, M. Inst. C. E.*

The bed of the river Thames within the county of London is now traversed by 13 tunnels, particulars of which are given in the table on page 664. Unsuccessful attempts to tunnel under the river were made in 1798 and 1805 and the celebrated Thames Tunnel was commenced in 1825. This (like all the later tunnels) was constructed by the aid of a shield, but it differs from its successors in being built of brickwork and being rectangular in cross section. The outside width of the brickwork is 37 ft. 6 ins. and the height 22 ft. 3 ins. The tunnel consists of two separate passages, with a dividing wall pierced by numerous openings. It was intended for highway purposes, but since 1865 it has accommodated the two tracks of the East London Ry. Great difficulties beset the work, the river breaking in on several occasions. After one of these irruptions the work was stopped for seven years, but it was again started in 1835 with a new shield and completed in 1842.

Though its completion reflects the greatest credit upon the celebrated engineer, Sir I. K. Brunel, who designed and carried out the work in the face of great difficulties, the Thames Tunnel was never a success financially. Partly, no doubt, for this reason 26 years were allowed to elapse before another tunnel was undertaken. In 1869 a small subway 7 ft. 1¾ ins. diameter was constructed under the river near the Tower of London by Mr. J. H. Greathead. This was the first tunnel to be built entirely of cast iron and surrounded by an envelope of lime grout. After a further period of 18 years the City & South London Ry. constructed twin tunnels near London Bridge and since then six other tube railway tunnels have been made under the river. The Blackwall Tunnel, for highway traffic, which closely resembles the one under construction at Rotherhithe, was opened in 1897, and the Greenwich footway tunnel in 1902.



SOUTH APPROACH AND PORTAL OF ROTHERHITHE TUNNEL (WITH BRIDGE OVER THE APPROACH TO THE ORIGINAL THAMES TUNNEL).

THE ROTHERHITHE TUNNEL.

The construction of this tunnel was undertaken by the London County Council in continuation of the policy first adopted in 1877 by its predecessor, the Metropolitan Board of Works. At that time ten bridges crossing the Thames west of the city district were freed to the public at a cost of $7,500,000. It was seen at the time that this expenditure, which was provided by the ratepayers of the whole of London, bore hard on those resident in the East End, to whom the freeing of these bridges was of little advantage. The great cost of bridging or tunneling the river below London Bridge, up to which navigation is open for sea-going vessels, caused considerable delay in the development of new schemes for communication below the bridge. During the last 20 years, however, four free crossings of the river have been provided: the Tower Bridge, the Greenwich and Blackwall tunnels, and the Woolwich free ferry. On the completion of the Rotherhithe Tunnel the inhabitants of London east of the City will be provided with five means of crossing the river against eleven west of the City, and the conditions will be more nearly equalized than in 1877. The number of bridges above London Bridge was then the same as at present, while below that point no free crossing at all existed. The only means then provided were the small Tower Subway, the East London Ry. (Thames Tunnel,) steam ferries at Greenwich and Woolwich, and watermen's rowing boats which were largely used in places.

A distance of over five miles by the windings of the river separates the Tower Bridge and the Blackwall Tunnel, and it was thought desirable to provide a means of crossing between these points. There are docks extending practically the whole distance on one side or the other, and to cross these by either tunnel or bridge would be almost impossible. The only line on which a tunnel could be built at about the position desired was the one adopted for the Rotherhithe Tunnel. At Shadwell and Rotherhithe, on the north and south sides respectively, the London & India Docks Co. and the Surrey Commercial Docks Co. have entrance locks almost opposite each other. by adopting an oblique crossing for the line of the tunnel, it passes east of the former and west of the latter docks, and although a longer subaqueous tunnel is required, it conforms better to the direction of the approaches than a direct crossing would have done. This is shown by the map and profile in Fig. 2. The approaches are necessarily inclined to the line of the river, in order that they may reach by reasonable grades the main thoroughfares in which they terminate.

The tunnel will provide a means of communi-

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TUNNELS UNDER THE RIVER THAMES AT LONDON, ENGLAND.

	Tunnel.	Location.	No. of Tunnels.	Outside Diameter. ft. ins.	Date of Completion.
1.	Thames Tunnel (now railway)	Rotherhithe to Wapping	1*	Rect.*	1842
2.	Tower Subway (footway)	Below London Bridge	1	7 1¾	1869
3.	City & South London El. Ry.	Above London Bridge	2	10 11	1887
4.	Blackwall Tunnel (highway)	Blackwall	1	27 0	1896
5.	City & South London El. Ry.	Below London Bridge	2	12 3¾	1898
6.	Waterloo & City El. Ry.	Above Blackfriars Bridge	2	13 7¼	1898
7.	Greenwich Tunnel (footway)	Greenwich	1	12 9	1901
8.	Baker St. & Waterloo El. Ry.	Above Charing Cross Bridge	2	12 9¾	1902
9.	Rotherhithe Tunnel (highway)	Rotherhithe to Ratcliff	1	30 0	1903

*Two arched openings separated by a partition wall having numerous openings. Size, 37 ft. 6 ins. × 22 ft. 3 ins. outside of brick masonry.

cation for vehicles and foot passengers between the large and important districts of which Stepney on the one side and Rotherhithe on the other are centers. At present the shortest route between the points at which the approaches join the existing streets is by way of the Tower Bridge; this is over three miles in length, through most congested districts. By the tunnel the distance will be 1.3 miles. An alternative route is by the Blackwall Tunnel, in which case the distance is about six miles. On either side of the new tunnel lie docks, wharves and warehouses of great importance, and it will afford a direct route from the Surrey Commercial Docks to the north and east parts of London. Advantage has been taken of the demolition of property necessary for the approaches to carry out considerable street improvement work. A new street has been formed in Rotherhithe, and several more on the north side of the river are being widened as part of the scheme. Most of the buildings pulled down were old and dilapidated. Under the Act of Parliament authorizing the scheme, the London County Council has to provide housing accommodation for persons displaced. For this purpose three blocks of artisans' dwellings with a total capacity of 2,640 persons have been erected.

GENERAL DESCRIPTION.—Commencing on the south side of the river in Lower Road, Rotherhithe (Fig. 2) the approach of the tunnel descends in open cutting for a distance of 934 ft., crossing the East London Ry. by a bridge. It then enters the cut-and-cover portion of the tunnel, which has a length of 540 ft. and terminates in No. 1 shaft. At this shaft the roadway is 44 ft. below ground level. The cast-iron lined, shield-driven tunnel begins here and descends on the same grade to No. 2 shaft which is situated close to the river. A distance of 890 ft. separates Nos. 1 and 2 shafts, and the tunnel passes under a metal refinery and the South Metropolitan Gas Works. From No. 2 to No. 3 shaft is the subaqueous section of the tunnel, 1,535 ft. long and nearly level, the up-grade beginning about 270 ft. from No. 3 shaft. At the southern end of this section (at No. 2 shaft), the tunnel attains its greatest depth; the roadway is here 75 ft. below ground level, and the invert of the tunnel lining 97 ft. below high water in the river.

From No. 3 shaft the tunnel rises on the same grade to No. 4 shaft, a distance of 1,155 ft. and passes round a curve of 800 ft. radius. The tunnel for the greater part of this distance is under buildings. The total length of the cast-iron lining is 3,580 ft. North of No. 4 shaft is a length of 600 ft. of cut-and-cover. This is followed by the open approach, which is 1,186 ft. long and terminates in Commercial Road East. The total length of tunnel and approaches is 6,883 ft., or 1.3 miles.

OPEN APPROACHES.—The open approaches, as may be seen in Fig. 3, which shows a typical cross section, consist of two side walls and an invert, all constructed of 6 to 1 concrete. The walls have a batter of 1 to 4 on the face. A watertight layer of asphalt 1½ ins. thick, applied in three coats, is carried down behind the side walls and through the invert. Brick parapet walls, 8 ft. high, are built on the top of the side walls. The roadway is 16 ft. wide between the curbs, and the two footways are 6 ft. wide. At the deepest points, at the entrances to the cut-and-cover, the roadway is about 25 ft. below ground level. On the south side of the river the approach crosses the Thames Tunnel approach of the East London Ry., at Rotherhithe station, by a plate-girder bridge, 64 ft. span, leaving headway underneath for the trains. This bridge has a solid trough floor. The old retaining walls, which were about 45 ft. high, were cut through and the new work substituted without interfering with the traffic. This is shown in the view of the approach on page 663.

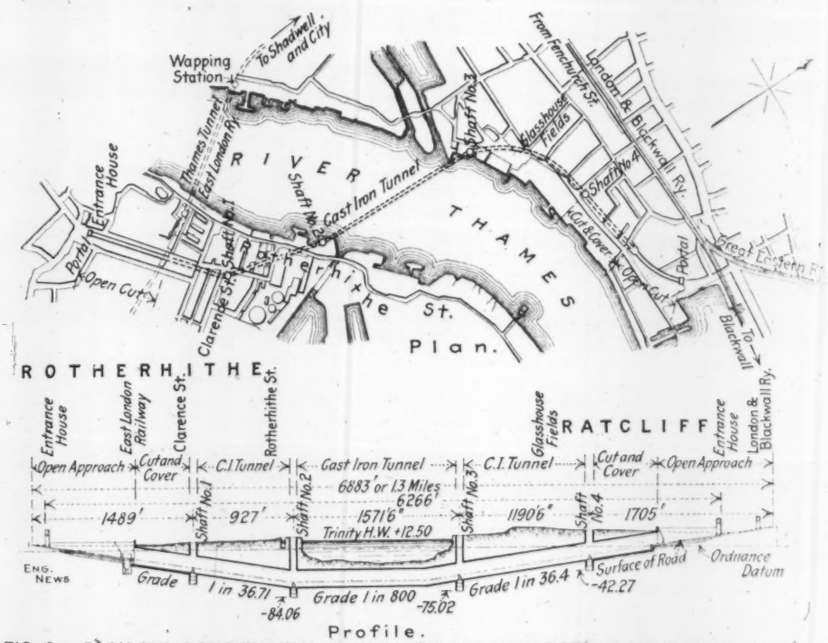


FIG. 2. PLAN AND LONGITUDINAL SECTION OF THE NEW ROTHERHITHE TUNNEL UNDER THE THAMES AT LONDON, ENGLAND.

CUT-AND-COVER.—Fig. 3 also shows the cross section of the work built in cut-and-cover. The excavation was taken out to the full width and depth and the water drained to a sump at the lower end, from which it was pumped. Heavy timbering was necessary. The tunnel is [illegible] in cross section and is built of five rings of [illegible] work surrounded with concrete, with a [illegible] asphalt outside the brickwork.

SHAFTS.—There are four vertical shafts on each side of the river. The two deeper are sunk as near the river bank as possible; the other two at the junctions of the cast-iron tunnel with the cut-and-cover sections. All shafts are circular in plan and of similar construction. Fig. 4 is a section of No. 3. They are 47 ft. 8 ins. clear diameter inside 60 ft. over the steel caisson. The caisson has two concentric cylindrical shells, 60 ft. and 50 ft. diameter, braced together, and having 32-ft. openings for the tunnel at the proper positions. These openings are lined with steel plating rigidly connected to the skins of the caisson. The cutting edge is formed by tapering out the inner skin to meet the outer at the bottom. About 13 ft. above the cutting edge is constructed an airtight floor consisting of a double system of intersecting plate girders, with their upper flanges all in the same plane. The spaces between these flanges are covered with ½-in. buckled steel plates.

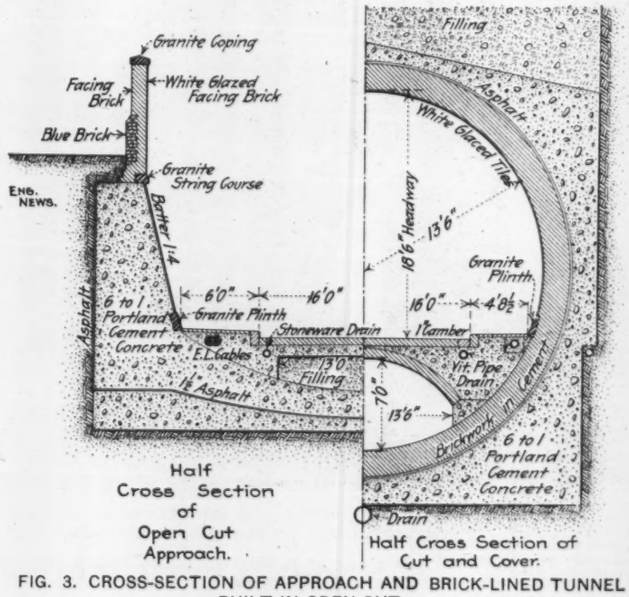


FIG. 3. CROSS-SECTION OF APPROACH AND BRICK-LINED TUNNEL BUILT IN OPEN CUT.

Above the tunnel openings referred to, provision was made in each shaft for a temporary airtight floor, beneath which tunneling under compressed air could proceed. The temporary floors are similar in construction to the permanent floors below, but are so arranged as to be easily detachable from the caissons. Fig. 5 shows the caisson for shaft No. 4 in process of sinking; the two 32-ft. openings for the tunnel are being temporarily closed by timber bulkheads until the caisson has reached its final position.

The spaces between the skins of the caissons were filled with concrete as sinking and erection proceeded, and after the final level was reached

space under the permanent airtight floor also filled up solid with the same material. Spiral staircases will be built in the two deeper shafts and all four will be covered by circular glazed roofs to admit light. Provision will also be made for ventilation.

CAST-IRON TUNNEL.—The tunnel proper, of which a cross section is shown in Fig. 6, has an outside diameter of 30 ft., and is 27 ft. diameter inside the finished surface of the lining. The clear headway in the center of the roadway is 18 ft. 6 ins. The cast-iron lining, of which details are shown in Fig. 7, is 2 ins. thick in the body in the subaqueous section, and 1¾ ins. elsewhere. The heavy lining weighs 41,500 lbs. per ring, and the lighter section 36,750 lbs. The flanges are 14 ins. deep. Each ring is 2 ft. 6 ins. wide, and consists of 16 segments and a key. There are 164 bolts of 1⅛ ins. diameter in each ring, and the circumferential holes are equally spaced all round, so that rings may be built in any position desired to break joint. Each segment is provided with a 1½-in. tapped hole for grouting purposes. Recesses for rust jointing, 2 ins. by ¼-in., are formed on the inner edges of all the flanges. These are calked, first with soft lead wire and then with cast-iron borings, as the erection proceeds. All the flanges are machined and in the case of the taper rings forming the curve on the north side of the river each ring was bolted together after the longitudinal joints had been machined, and the circular flanges were then faced in a specially constructed lathe. The cast-iron segments will be filled up with concrete after erection, the exposed surface being covered with white glazed tiles. The tiled face is 4 ins. beyond the flanges of the segments. The lighting of the tunnel will be by three rows of electric incandescent lamps.

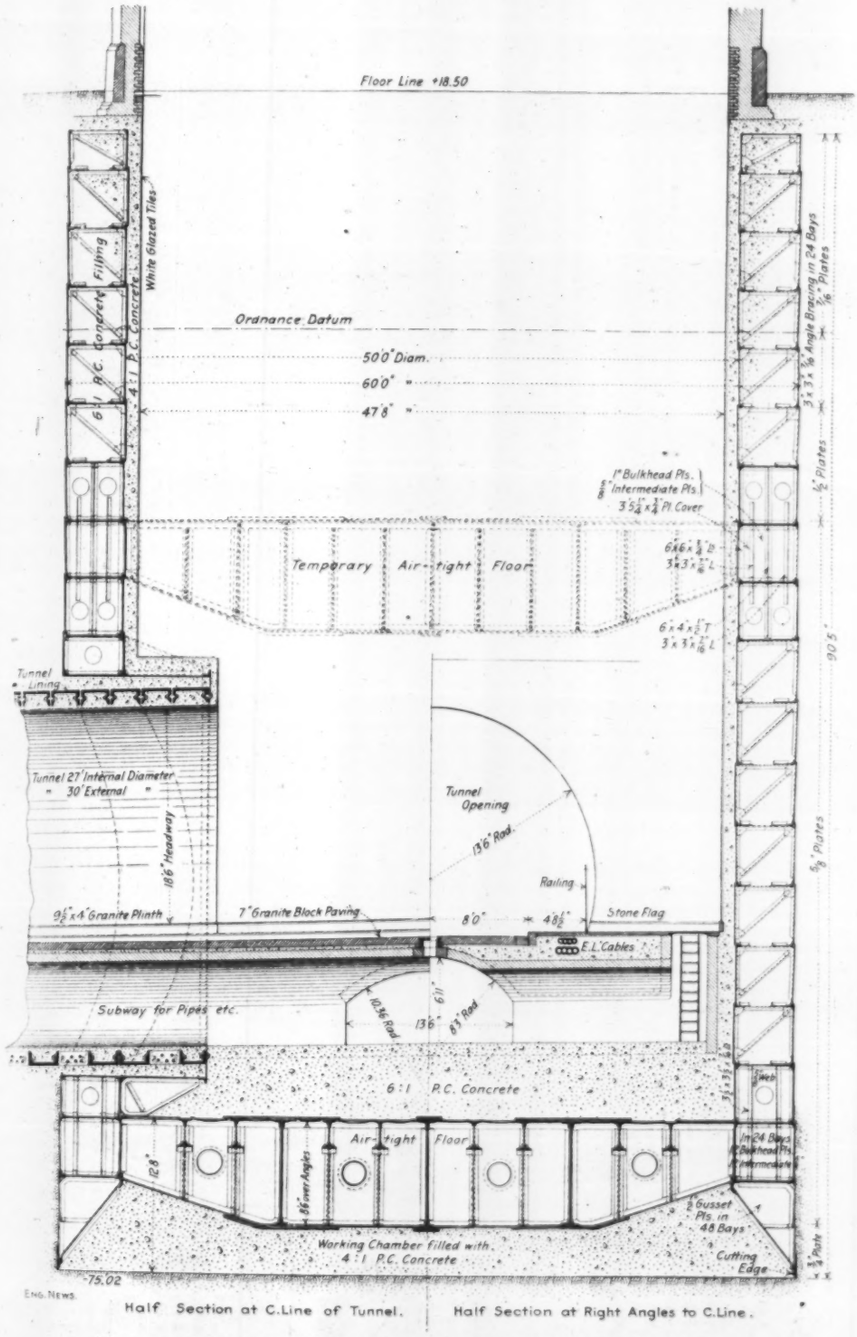


FIG. 4. SHAFT NO. 3 OF THE ROTHERHITHE TUNNEL.

ROADWAY.—The roadway in the tunnel proper and the cut-and-cover sections is carried on a 9-in. brick arch, leaving a subway 13 ft. 6 ins. wide underneath, which can be utilized for water or electric mains. The surface drainage from the roadway is provided for by pipe drains at each side, which discharge into a sump at the bottom of No. 2 shaft. From this the water will be pumped to the surface. The 16-ft. roadway is paved with granite blocks on the inclines (which have a grade of 2.77%) and with compressed asphalt on the nearly level portion under the river. The footways are 4 ft. 8½ ins. wide, and laid with York stone flags.

CONSTRUCTION PLANT.—The machinery for producing compressed air and hydraulic and electric power is located near No. 3 shaft, from which the tunneling in both directions was started. There are six compound condensing air-compressors, together capable of dealing with 1,000,000 cu. ft. of free air per hour. Also six smaller compressors for the supply of high-pressure air for grouting and power purposes. Two compound hydraulic pumping engines deliver high-pressure water to two accumulators, and there are four direct-connected electric generator sets for light and power. Steam is supplied by seven boilers of the marine type and the condensing water is cooled in a tower.

AIR LOCKS.—The arrangement of air chamber and locks used in connection with the airtight floors in No. 3 shaft is shown in Fig. 8. This arrangement was used first for sinking the caisson when the air shafts were connected to the lower airtight floor. It was afterwards used for starting the tunnel, when the air shafts were connected to the upper (temporary) floor, the air chamber and locks being, in the latter case, raised to a higher level. The dump cars containing the excavated material were lifted in cages operated by hydraulic hoists inside the air shafts, and the cars ran direct from the cages into the air locks, each of which held two cars.

BULKHEADS.—Fig. 9 illustrates the bulkheads used in the tunnel, of which four have been built. The bulkheads in previous compressed-air tunnels have usually been built of brickwork or concrete. The adoption of steel in this case was due to the rapidity with which a steel structure, when suitably designed, can be erected or removed. The bulkhead consists of a diaphragm of ⅝-in. steel plates, stiffened by rolled steel I-beams, and supported by vertical and horizontal girders radiating from the center. The thrust at the center due to the air pressure is transmitted to the iron lining of the tunnel by four diagonal struts. There are three air locks; the small upper one is intended for use in emergency, in the event of the lower locks being submerged by an inrush of water.

SHIELDS.—The shield used for tunneling under the river, illustrated in Fig. 10, is 30 ft. 8 ins. diameter and 18 ft. long. It consists of three rings of cast steel segments bolted together and a tail, or skin, of three thicknesses of ¾-in. steel plates. Vertical and horizontal partitions divide the front portion of the shield into 16 compartments for working purposes, and Fig. 11 is a view of the face, as it entered No. 2 shaft after completing a length of tunnel. On the vertical partitions are fixed hydraulic jacks for supporting the timbers which secure the face while advancing in soft ground. These are plainly visible in some of the left hand compartments in Fig. 11. The main shield jacks are 40 in number and have rams of 9 ins. diameter with a stroke of 3 ft. 6 ins. They are connected to the operating valves in pairs, so that any two rams can be worked independently. The total pressure exerted may be as much as 5,000 tons. At the rear end of the two outer vertical partitions are fixed the two hydraulic erectors for handling the iron lining segments. These are shown in Fig. 12. The second shield which was used for driving the tunnel on the north side of the river only is similar to the first, but about 5 ft. shorter to enable it to pass easily round the curve.

A steel working stage about 50 ft. long travels behind each shield and carries hydraulic pumps, grouting pans, etc., being also used as a working platform for bolting up the lining and calking. This is shown in Fig. 13, while Fig. 14 shows the timber traveler used in completing the bolting and calking.

EXECUTION OF THE WORK.—The condition of the work (May, 1907) is as follows: The open approaches on both sides of the river are finished with the exception of the facing to the walls. The cut-and-cover section on the south side is complete and a portion of that on the north side. All the shafts are sunk, and the river wall is built. The tunnel under the river is finished, with the exception of the concrete lining, and about 400 ft. has been driven under the land in each direction. It is expected that all the tunneling will be finished by September of the present year, and the whole work in the summer of 1908.

The erection of the first caisson, No. 3, was commenced in October, 1904, and sinking about two months later. At a depth of 26 ft. water was met with and sinking was suspended for two months, while the airtight floor and all arrangements for working with compressed air were completed. Air pressure was applied on May 22, 1905, and the caisson was sunk the remaining 70 ft. to its final level in less than ten weeks. The maximum air pressure used was 17½ lbs. per sq. in., which is considerably less than the hydrostatic head of the water in the river. The weight of the caisson itself, with the concrete between the skins, was sufficient to cause it to sink.

The sinking of Nos. 1 and 4 shafts, which are only about 70 ft. deep, presented little difficulty. Compressed air was not used and very little pumping was necessary. In sinking No. 2 shaft, a maximum air pressure of 20 lbs. per sq. in. was required. The shaft reached its final level in July, 1906.

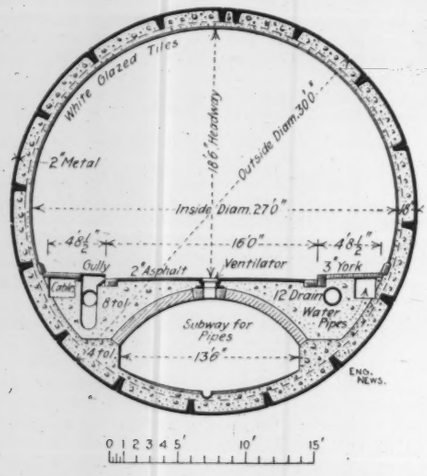


Fig. 6. Transverse Section of the New Rotherhithe Tunnel.

TUNNELING.—As soon as No. 3 shaft had been sunk, the space under the airtight floor was filled with concrete and the air pressure taken off so that the erection of the shield could be proceeded with. In the meantime it had been decided to drive a heading or small pilot tunnel across the river, so as to ascertain definitely the nature of the ground to be met with. This heading was 12 ft. 6 ins. diameter and lined with cast-iron segments, its top being about 2 ft. below the top of the main tunnel. For driving this heading one of Price's excavators was used. This machine, illustrated in Figs. 15 and 16, consists of an ordinary shield, fitted with ten 7-in. hydraulic jacks for driving it forward in the usual way, and provided with a rotary cutting head in front of the cutting edge. This cutting head is fitted with a series of tools for breaking down the material and with dredge buckets which discharge it into a shoot from which it is removed by a belt conveyor and delivered into cars in the tunnel behind the shield. The cutting head is rotated by an electric motor through spur gearing and the tools are kept up to the face by the hydraulic jacks which keep the shield slowly advancing as the head rotates.

Air pressure was put on under the temporary airtight floor of the shaft and the excavator started on Oct. 12, 1905. A few weeks later a brick bulkhead was built in the small tunnel behind the shield and air pressure again taken off the shaft so that the erection of the main shield could proceed under atmospheric conditions. The progress of the excavator was somewhat delayed by the presence of a seam of rock which extended across the river bed, but it arrived at a point 150 ft. from No. 2 shaft on Jan. 22, 1906, where it was stopped. The average rate of progress was 13 ft. 6 ins. per day of 24 hours and the air pressure used varied from 12 to 21 lbs. per sq. in., according to the state of the tide in the river.

In the meantime the large shield had been built in No. 3 shaft; compressed air having been again applied, this shield started on its journey across the river in the beginning of February. As the strata met with in the small tunnel proved satisfactory, little trouble was anticipated and steady progress was made from the beginning. Very little support was required for the face, which was usually excavated 2 ft. 6 ins. in front of the shield except near the outer edge, where some of the material was left to be removed by the shield at each advance. One or two rings of the small tunnel, which were 20 ins. wide, had to be removed in excavating each length. The strata met with were clays, marls and gravels forming part of the deposit known as the "Woolwich and Reading beds," and contained little water. Fig. 17 shows the arrangement of the strata and the position of the pilot tunnel with relation to the main tunnel.

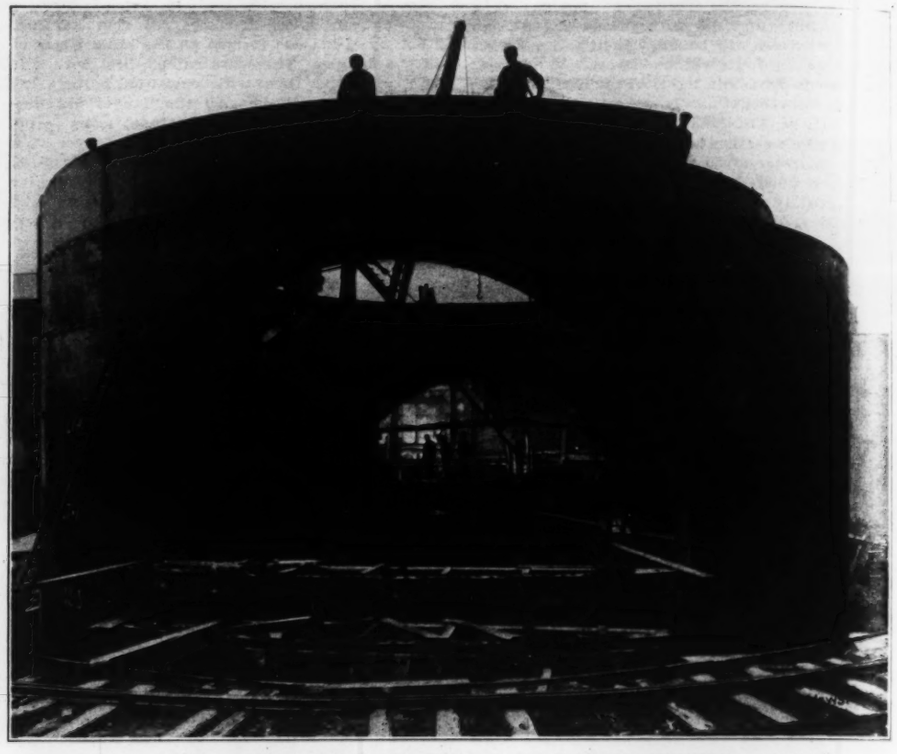


FIG. 5. SINKING CAISSON FOR SHAFT NO. 4 OF THE ROTHERHITHE TUNNEL.

A bulkhead was built in the tunnel about 300 ft. from the shaft, and half the distance across the river was accomplished in six months from the start. The second half was driven in three months more and the shield arrived in No. 2 shaft on Nov. 21, 1906. The average rate of progress for the whole distance was 40 ft. per week, and the best week's work was 62½ ft.

The alinement of the tunnel was carried out in the usual way by the prolongation of a line joining two plumb lines, suspended in the shaft, and the shield was kept to line and level without difficulty. The lining of the tunnel is usually within 1 in. of its correct diameter vertically and horizontally and no deformation after erection has been observed, the breaking joint of the rings giving great stiffness to the structure. Owing principally, no doubt, to the low air pressure found necessary very little compressed air illness has occurred. All the workmen are medically examined. Special attention is also given to the ventilation of the tunnel, a large amount of excess air being pumped into the supply mains, and blow-out pipes being always kept open. All

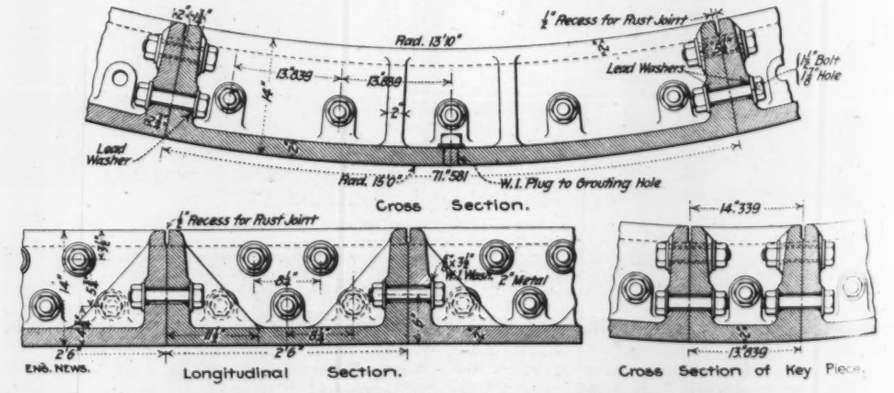
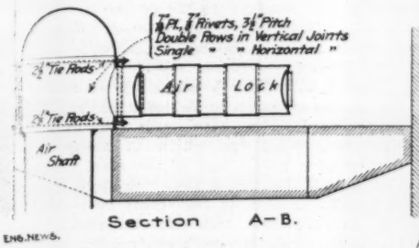


FIG. 7. DETAILS OF CAST-IRON LINING; ROTHERHITHE TUNNEL.

...k in compressed air is carried on in three ...fts of eight hours each.

...e total estimated cost of the scheme is about ...00,000, of which about half is for the en...ering works. The whole of the work is being carried out by Price & Reeves, the contractors, under the supervision of Mr. Maurice Fitzmaurice, M. Inst. C. E., the Chief Engineer of the London County Council, who is also responsible for the design. The writer is Resident Engineer for the London County Council.



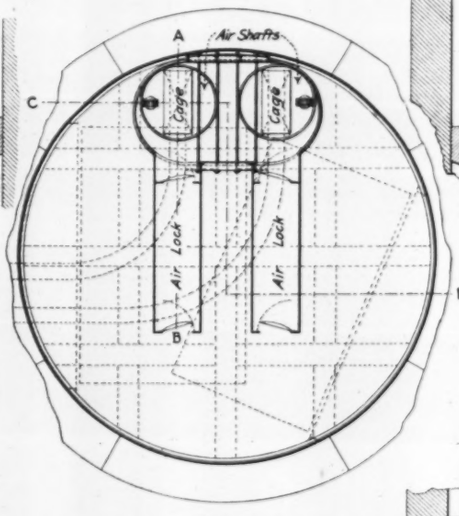
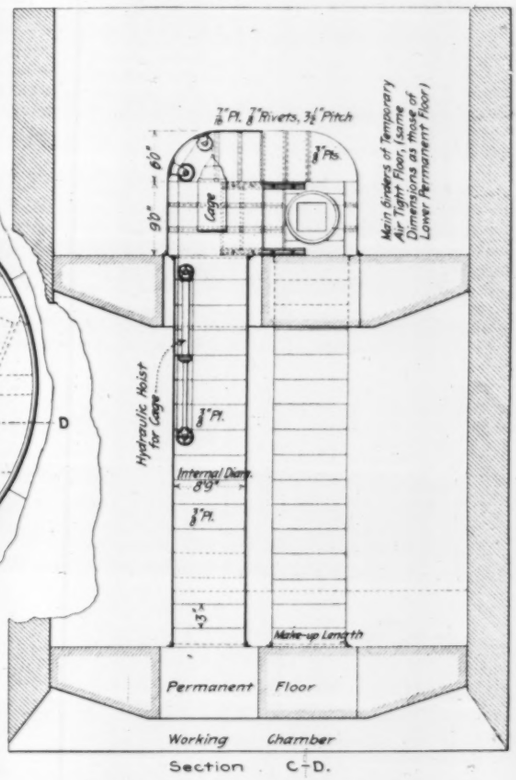


FIG. 8. AIR-LOCKS AT SHAFT.



COST OF CONSTRUCTING STEAM-DRIVEN ELECTRIC POWER PLANTS.

By FRANK KOESTER.*

The cost of steam power plants is determined by the location and by the character of the building and equipment. The amount of capital available also plays an important part in determining the equipment. Mistakes have been frequent in selecting the type and size of various portions of the equipment, and in such cases it has been evident that the use of other machinery (perhaps lower-priced) would bring better results. Herein the broadness of experience in the designer counts largely. It is not the province of the designer to design special machines but to properly select machinery already on the market. Such a broad experience is necessary to secure that judgment in selection which it is evident many designers lack. A thorough business knowledge is essential for securing the most suitable machinery at a minimum of expenditure. The proper and economical assembling of the various parts needs to form an important part in the designer's experience.

The figures given herein for the cost of power plants are derived from plants whose designers may be said to fairly fulfill the above requirements. These costs represent an average arrived at by the comparison of costs of various plants with which the writer has been connected, directly or indirectly in one way or another, during a considerable experience in the design and erection of such works. The costs represent recent practice and are quoted per KW. capacity.

BUILDING.—Judgment in the architectural treatment and the selection of stock sizes of doors and windows will very materially keep down the first cost of the building. Some of the more prominent plants of the country vary widely in the cost of their superstructure, and it cannot always be said that the more expensive building is the most pleasing to the eye. In the design of the superstructure, the character of the building as a power plant must be kept in mind. Comparatively the cost of the superstructure for a plant of small capacity will be greater per KW. capacity than the cost of the larger plant. The superstructure for plants up to 5,000 KW. capacity costs from $15 to $25 per KW. The former figure may be secured by a compact arrangement with walls of common brick, wooden doors and window frames, steel roof trusses supported by the walls and a roof of the cheapest fireproof construction, such as corrugated iron, tin, etc.

The other type of building, costing about $20 to $25 per KW., may be constructed of higher grade masonry with fireproof windows and doors, roof trusses carried by steel columns which at the same time carry the crane runway, and the roof itself consisting of reinforced concrete covered by tar and gravel.

The cost of the superstructure for large size plants usually runs from $10 to $20 per KW. These are constructed of a self-supporting steel skeleton and self-supporting walls. The superstructure at $20 per KW. may embrace multiple boiler floors while those at $10 per KW. cover single boiler floor plants only. In both cases coal bunkers are provided. In the lower cost building steel bunkers of five to eight tons capacity per running foot are installed. In the multiple boiler floor building the bunkers are made up of structural steel, the beams being filled in with masonry arches, the side walls also being of masonry filling.

CHIMNEY.—The cost of the chimney depends largely on the location of the plant, the proximity to the source of the particular kind of materials constituting an important factor, as the cost of transportation of materials is a large item, steel chimneys being cheaper in such localities where transportation costs favor such construction.

Furthermore, the competition among builders of chimneys, and especially since the introduction of the reinforced concrete chimney, is so strong that a radial brick chimney may sometimes be had as cheap as a steel chimney or reinforced concrete chimney.

A radial brick chimney for large sized power plants may be built from $1.75 to $2.25 per KW. Reinforced concrete chimneys and plate steel chimneys may cost from $1.50 to $2 per KW.

COAL AND ASH HANDLING SYSTEMS.—The cost of coal and ash handling systems is difficult to determine, depending so largely as it does upon the manner in which the coal is received from the shipper, the way the ashes are disposed of and the distance through which the coal as well as the ashes must be handled. Experience shows that the figures for equipment for handling coal and ashes range from $1.50 to $3 per KW.

BOILERS.—The cost of water tube boilers ranges from $8 to $10 per KW., depending upon the square feet of heating surface in the boiler. These figures do not include mechanical stokers, for which from $2 to $3 may be assumed. Breeching, of course, is also a separate item and

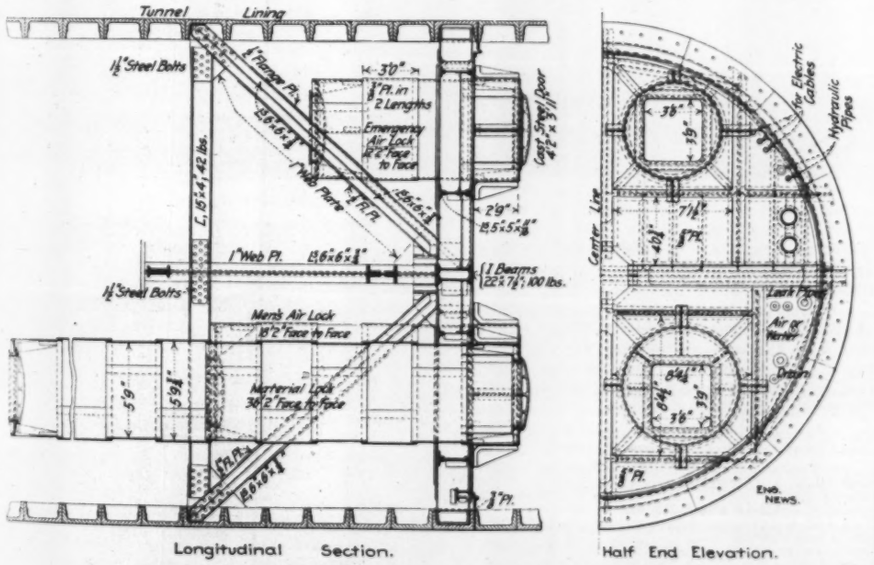


FIG. 9. STEEL BULKHEAD IN THE ROTHERHITHE TUNNEL.

*Consulting Engineer, 400 West 57th St., New York City.

varies considerably as to cost per KW. The boiler setting is included in the cost of boiler given above.

BLOWERS.—In many of the modern power plants, especially plants for railway purposes, forced or induced draft is adopted. The blowers are usually steam-driven. The cost of such equipment is about $1 per KW.

ECONOMIZERS.—Where economizers are installed of sufficient capacity to heat the water to 200° or 220° F. such apparatus costs about $2 per KW., provided that there are not too many additional smoke flues necessary for by-passing, etc.

BOILER FEED PUMPS.—The cost of such pumps alone is some 50 cts. per KW. When storage tanks are necessary the cost of the combined outfit amounts to 75 cts. or $1, depending on the number and size of the tanks.

PIPING.—In some stations piping has been installed for $2 per KW., while in others as high as $6 per KW. has been paid. This includes all high and low-pressure piping (steam and water).

For plants varying from 10,000 to 20,000-KW. capacity, the piping system not being elaborate but sufficient for continuous operation, $2.50 to $2.75 has covered the cost. This includes a high grade of covering for steam piping valued at about 20 cts. per KW.

PRIME MOVERS.—While the price of the prime movers varies with the size of the units, it also varies with the type of machine. The price of turbines is often governed by the price of reciprocating engines, although the former can be produced cheaper than the latter. Although the condensers for a turbine cost more than for a reciprocating engine the complete turbine generating unit ordinarily should cost considerably less. A 5,000-KW. turbo-generator should cost from $20 to $22 per KW. Reciprocating engines of this capacity are sold roughly at the same price, and about $10 per KW. needs to be added for the generator. The total cost for smaller units, 600 to 3,000 KW. capacity, is from $20 to $25 per KW., whether they consist of turbine or reciprocating-engine apparatus.

CONDENSERS.—The cost of condensers depends very much upon the vacuum desired and on the type of condenser. The cost of jet condenser equipment runs from $3 to $5 per KW., depending upon the type of pump used. The cost of surface condenser apparatus will vary from $5 to $8, depending partly upon the vacuum to be carried and whether the casing necessary forms part of the condenser equipment or is provided as part of the turbine shell, as is the case in the Curtis base-condenser turbine, in which case the above figures may fall as low as $3 per KW.

EXCITERS.—A steam-driven exciter unit costs from 35 cts. to 40 cts. per KW. If a condenser should be installed in connection with it the cost may run as high as 70 cts. per KW., assuming that the exciter capacity is, approximately, 1% the total capacity of the plant.

SWITCHBOARDS.—In considering the cost of a switchboard equipment only such switchboard is herein considered as is necessary for the operation of the plant and the outgoing feeders, not including substation boards. The cost will vary with the voltage adopted for the system. For a high tension voltage the cost will run from $2 to $3.50, while for a low tension voltage (2,300 volts and lower) the switchboard equipment may be obtained for $1 to $2 per KW., depending largely upon the system of wiring adopted.

MISCELLANEOUS.—There are many other items, which must be figured in the complete cost of the plants, such as traveling cranes, which will amount to 25 or 50 cts. per KW. Smaller items like house pumps, water mains, blow-off tanks, painting, supervision, etc., will total from $1 to $2 per KW.

TABULATIONS.—A summary of the preceding figures is shown in Tables I. and II. To the summarized costs there needs still to be added the engineering fee which in many cases is figured as a percentage on the total cost.

It should be noted that the first column of figures in each table represents costs which are exceptionally low and may be attained under favorable conditions with engineering skill. The second column of figures in each table represents fair average figures as ascertained from the cost of a number of plants recently erected. However, plants have been installed which cost as much as $125 per KW., and in an exceptional case the cost approximated $150 per KW.

All of these figures represent costs of plants of large capacity. Small plants of about 3,000 KW. capacity have been erected in the West at from $120 to $130 per KW., which costs may be reduced if a simple combination of machines is provided.

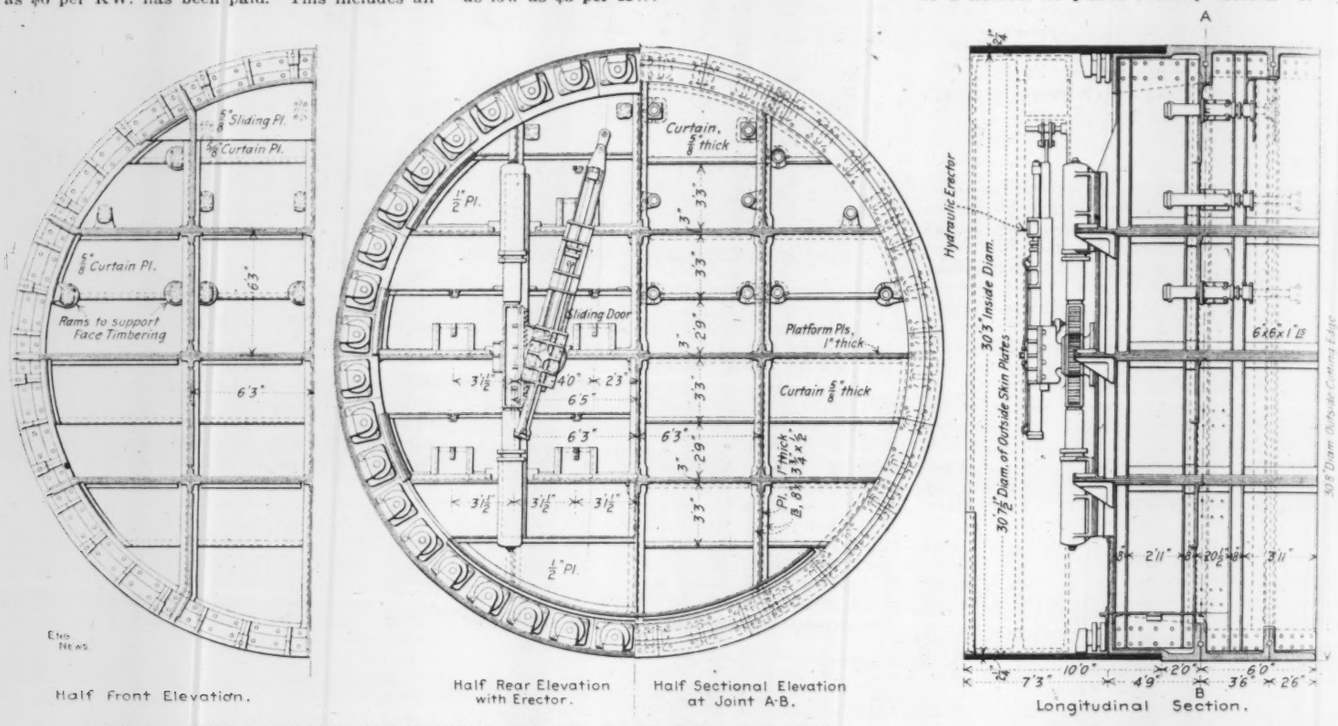


FIG. 10. SHIELD FOR THE ROTHERHITHE TUNNEL (30 FT. 8 INS. DIAMETER).

TABLE I.—COST OF STEAM TURBINE PLANTS.

Excavations and foundations	$2.00	$2.50
Building	10.00	15.00
Tunnels (condenser water conduit)	1.75	4.00
Flues and stacks	2.50	3.50
Boilers and stokers	8.50	12.00
Superheaters	2.00	2.50
Economizers	2.00	2.25
Coal and ash handling systems	1.50	3.00
Blowers and ducts	1.00	1.50
Pumps and tanks	1.00	1.25
Piping systems	2.25	4.50
Turbo-generators	22.00	25.00
Condensers (surface)	5.00	8.00
Exciters	.75	1.00
Crane	.25	.50
Switchboards	2.00	3.50
Plumbing, painting, labor, etc.	1.00	2.00
	$65.00	$103.00

TABLE II.—COST OF RECIPROCATING ENGINE PLANTS.

Excavations and foundations	$3.00	$5.00
Building	10.00	20.00
Tunnels (condenser water conduit)	1.50	2.75
Flues and stacks	2.50	3.50
Boilers and stokers	8.50	12.00
Superheaters	1.75	2.25
Economizers	2.00	2.25
Coal and ash-handling systems	1.50	3.00
Blowers and ducts	1.00	1.50
Pumps and tanks	1.00	1.25
Piping systems	2.50	5.00
Engines	18.00	22.00
Condensers, jet	3.00	5.00
Exciters	.75	1.00
Generators	10.00	12.00
Crane	.25	.50
Switchboards	1.00	2.00
Plumbing, painting, labor, etc.	1.00	2.00
	$70.25	$104.50

Referring to these tables, it will be observed that the turbine plant varies from $65 to $103 per KW. The main items constituting this difference are: building, turbo-generators and condensers. The difference in cost of these is due to the type of turbine, the size and make of condensers and their auxiliaries, as well as the manner of assembling, all of which may reduce the size of the building required.

The difference in cost of boilers is due to the make or type and the rating of the boiler horsepower adopted by the plant designer per KW. capacity. This ratio varies greatly. Plants have been installed with the same type of boiler and the same type of prime mover in which the ratio varies, one value being 0.60 boiler horsepower per KW. generator capacity, while in other cases it is 0.75, and 0.80. This difference depends upon the experience and judgment on the part of the designer as well as the estimated ability of the future available operating force to produce steam effectively.

The difference observed in the cost of the other items may be explained by the difference in the grade of material used and the ability of one purchaser over another to secure the lowest market price.

FIG. 11. FACE OF SHIELD (ENTERING THE SHAFT).

A PRIZE OF $100 for the best essay on "The Economic Waste of Accidents" is offered by the American Museum of Safety Devices and Industrial Hygiene. The committee to award the prize is made up of Messrs. Richard Watson Gilder, Editor of "The Century Magazine"; George Gilmour and W. H. Tolman.

The museum desires exhibits of devices and processes for safeguarding life and limb in connection with woodworking machinery, railway and marine transportation, mining, agriculture, manufacturing of all kinds. Professor F. R. Hutton, past-president of the American Society of Mechanical Engineers, is the Chairman of the Committee on Admission of Exhibits.

All exhibits accepted by the committee will be eligible for the gold medal offered by the "Scientific American" for the best device, exhibited at the museum, for safeguarding life and limb. All inquiries regarding exhibits should be sent to Dr. W. H. Tolman, Director, 231 West 39th St., New York.

THE COST OF HYDRO-ELECTRIC POWER DEVELOPMENT IN THE PROVINCE OF ONTARIO.

The Hydro-Electric Power Commission of the Province of Ontario has undertaken a complete study of present and future power conditions in the Province. The country has been divided for this study, into several natural divisions, the results of the investigations in which are grouped into five reports. The first report deals with that part of southwestern Ontario which lies, roughly speaking, north of the latitude of Toronto and which has been called the Niagara District. The second report deals with that portion of the province north of Lake Ontario, but not including Toronto; this is called the Trent District. The third report shows the investigations in that area bounded on the west by Lake Huron and Georgian Bay, on the south, east and north by the districts of Niagara and Trent. This area is called the Lake Huron and Georgian Bay District. In the fourth report the commission has presented the work in a portion of Ontario east and north of the Trent and the Lake Huron and Georgian Bay districts known as the Ottawa Valley and St. Lawrence River district. In the fifth report is included the judicial districts of Algoma, Thunder Bay and Rainy River in the north of the province, but omitting the sparsely settled area north of the height of land in these judicial districts.

This commissioner was directed to investigate and report on several phases of the situation:

(1) The present and probable demand for hydraulic and electrical power in the various districts capable of being supplied from the different water-powers within the jurisdiction of the Province.

(2) The location, capacity and capital cost of development of the various water-powers within the legislative jurisdiction of the Province at present undeveloped, but whose development is required to supply the present and probable needs of the surrounding districts; and the probable costs of the attendant transmission plant necessary for the utilization of electrical and hydraulic power.

(3) The rates that must be charged the various classes of users of hydraulic or electric power within the respective districts in order to meet all expenditures of maintenance and operation.

(4) The annual saving accruing to the customers in the various districts by the substitution of the rates or prices of (3) for rates paid at present in the various districts.

(5) The cash capital costs of the hydraulic and electrical power undertakings of existing companies located within the Province of Ontario; the capacity and the state of development thereof.

The results of the investigations in the five districts mentioned above have been well tabulated and summarized by the engineers of the Commission. As the figures obtained may be considered indicative of the estimated cost of pioneer development work and may be of assistance in similar work under similar conditions, existing widely in this country, some of these results have been further collected, summarized and rearranged so as to be more directly comparable. Enough of the conditions for which these estimates were prepared are outlined in this article so that the limitations in the use of these tables should be easily recognized.

As a basis for estimates in demand for power a full canvass was made by expert assistants in each town and city. Great care was taken to determine whether or not the consumer would be likely to adopt electric power if it were available, and a distinction was made in the case of power users who required steam for other purposes or who had refuse material available as fuel and who consequently would not be apt to make a change in their source of power.

In estimating the total power to be distributed in each municipality it has been arbitrarily assumed that by the time transmission lines could be completed and with power for sale at reasonable figures the total demand which should be provided for would be 25% greater than present estimates. On this basis weight of copper was calculated.

Having determined the cost of 24-hr. power to various municipalities, its distribution was to be considered separatively for customers in each town or city. Owing to the great amount of labor involved in working out the costs of a system for each small place it was considered sufficient to take typical cases and apply the results more widely. Little variation was found in the cost of distribution in places of moderate size where underground distribution was not necessary.

In the estimates on which the cost data table has been compiled, depreciation and replacement charges have been figured so as to replace the different classes of equipment in periods ranging from 15 to 40 years. The depreciation charges are held as sufficient to serve as a sinking fund. However, in the case of the generating station estimates, the depreciation figures do not include enough to replace the so-called permanent portions of the development such as dams, head works and power-house. If a 40-year sinking fund large enough to cover these items is considered necessary a charge on some $45 to $65 per HP. of capacity would need to be made. At 3 or 4% a charge of 60 to 80 cents per annum per HP. would meet the requirements. The given annual charges include depreciation, repairs and interest during construction. The transformation charges include municipal taxes on building, insurance, depreciation and 20% for engineering contingencies and interest during construction.

In Table II. a statement is made of the rates for current charged during 1906-07, in the districts investigated.

To complete the information presented regarding the cost of electric power to the consumer, Table III. was arranged showing the cost of induction motor service. By combining the results of this table with the cost of power as fixed at any certain city or town, and with a calculated cost of distribution from the municipal substation to the consumer, a total cost per HP. year may be obtained. Such a charge then represents the estimated annual charge including all items from generation to utilization inclusive. The cost of the distribution to the customers from the proposed municipal substations varies

greatly with the distances, with the demand for power and with the grouping of the customers.

Any specific case is not apt to be as simple even as indicated above, for each municipality has varied means of modifying the simply calculated rates. Among these means may be mentioned limited-hour and summer contracts, services with peak loads at different hours, etc., etc. The Hydro-Electric Commission expects that, under the average conditions in a town needing at least 1,000 HP., 10-hr. power could be furnished manufacturers at the same or at a lower rate (on maximum demand) than that charged the municipality for the 24-hr. supply. The muhicipality would then be expected to profit from non-lapping loads enough to pay the cost of local distribution. As the larger proportion of power is used for 10 hrs. only, though sold on a 24-hr. price, this power will be available for municipal lighting and pumping after 6 p. m. free of cost or at greatly reduced cost to the municipality. The ultization of idle transmission lines, during the nights, for municipal pumping will be dependent on having sufficient storage capacity in reservoir or standpipe to supply through the day. However, as in the winter season, there is a period between 4.30 and 6 p. m. during which the municipal lighting is not provided for. In order to have free or cheap power for lighting, all the year around, it becomes necessary to make "limited-hour contracts" by which certain motor users will agree to shut down at about 4.30 p. m. for some five months each year.

In order to institute a comparison between the cost of electric power and that generated by steam or producer gas, Tables IV. and V. were arranged. The data were compiled from those available in technical journals and from figures obtained by the Commission's engineers in various towns within the districts. The capital costs were figured from information supplied by manufacturers. The tables are held to represent average working conditions and assume a high-class installation.

To make these tables available for use under varying conditions of coal supply, Table VI. was arranged to show the effect in the cost of power by the price of coal varying 50 cts. per ton.

NIAGARA DISTRICT.

GENERATION OF POWER.—The only source of hydro-electric power requiring consideration is the water of Lake Erie utilized at the Niagara escarpment, at various points up to some 20 miles westward from Niagara Falls. Further west the backbone between the escarpment and Lake Erie becomes too pronounced. The Niagara developments partially completed are capable of supplying any demand likely to arise in Ontario in the near future. There is now (Jan. 1, 1907) some 150,000 HP. immediately in sight, with the permanent works designed for 425,000 HP., 24-hr. power. The net effective capacities of the district are distributed as follows (with proper allowance for necessary spare units): Hamilton Cataract Power, Light & Traction Co., 22,500 HP., 10-hr.; Canadian Niagara Power Co., 40,000 HP., 24-hr.; Ontario Power Co., 50,000 HP., 24-hr.; Electrical Development Co., 37,500 HP., 24-hr.

In dealing with the generation of power the Commission studied the situation from two points of view: (1) the purchase of power; (2) the construction of a new generating plant. On account of the existing power companies on the Canadian side of the Niagara river, and as transmitting systems can be constructed in a shorter period of time than generating plants, as the distribution of power will naturally commence with a small demand, increasing yearly, it is considered a better course for a transmission company to purchase the power, and the calculations on which are based the cost of power delivered at municipal substations as shown in Table I., have been based on an arbitrary price of $12 per 24-hr. HP. per annum at the high tension bus bars of the generating station. This figure was decided upon with the knowledge of recent sales of large blocks of power at Niagara.

However, should it be found advisable to construct a new generating plant at Niagara Falls, it would take fully four years for completion. Such a plant would be situated above the intake of the Ontario Power Co.'s plant about 4,000 ft. below the Welland River, the cheapest and most suitable location now available on the Canadian side. Such a plant would require a [illegible]-ft. tail-race tunnel. There are strong reasons why a plant located about 18 mi. west of Niagara Falls would be more adapted to the Canadian needs. The water could be used at a 300-ft. head, about twice that available at the Niagara Falls site mentioned. The construction would not disfigure the vicinity of the falls and 18 mi. of transmission would be saved.

The estimates for the Niagara District portion of the accompanying table of power costs are based on the purchase of a private right-of-way over the entire district, 100 ft. wide between Niagara and Hamilton, 66 ft. wide between Hamilton and Toronto, and 33 ft. wide alongside of highways and railways for the smaller lines. Steel tower construction, either double or single type, according to the number of trunk lines. Branch lines are estimated for first-class cedar pole construction.

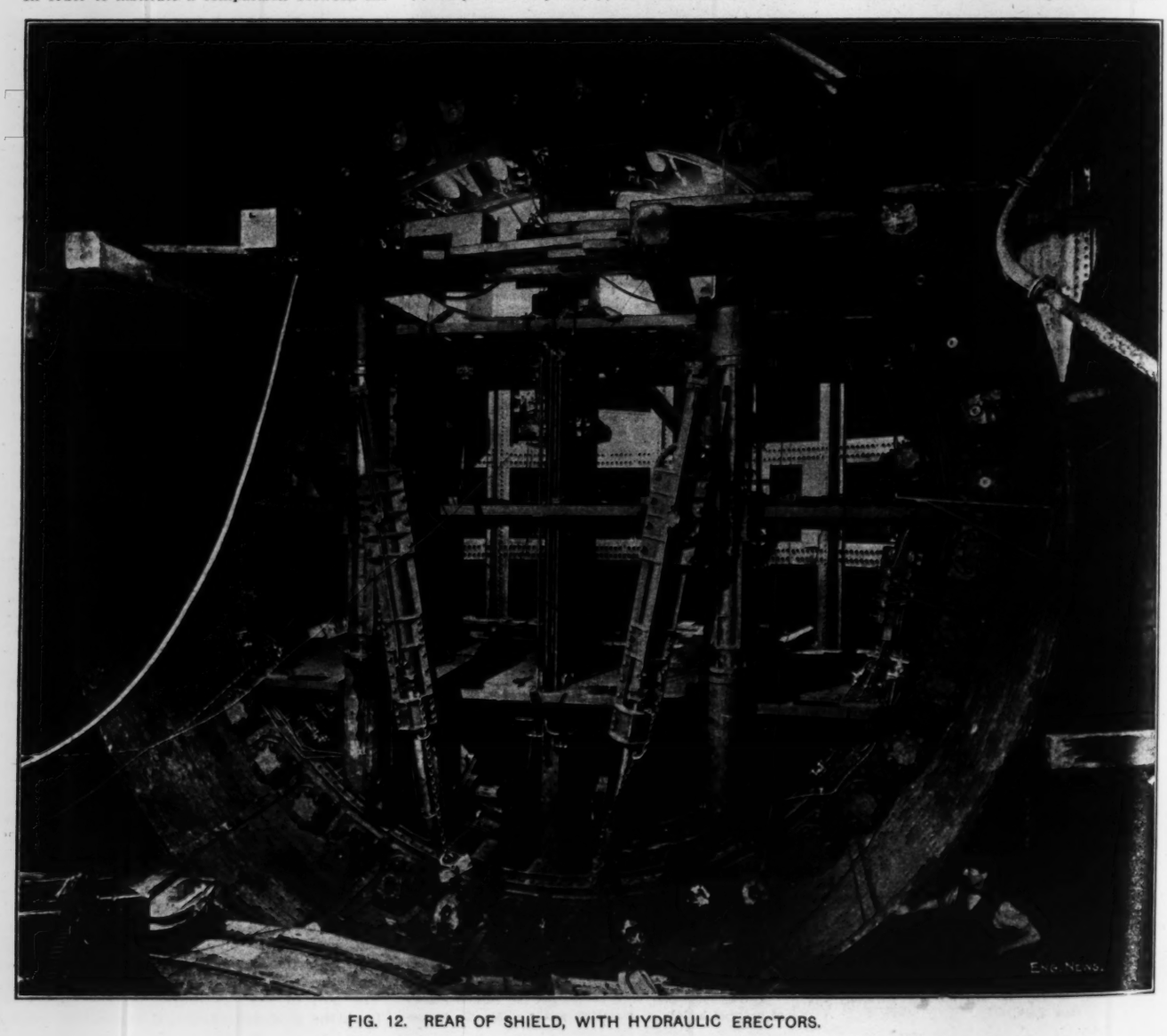


FIG. 12. REAR OF SHIELD, WITH HYDRAULIC ERECTORS.

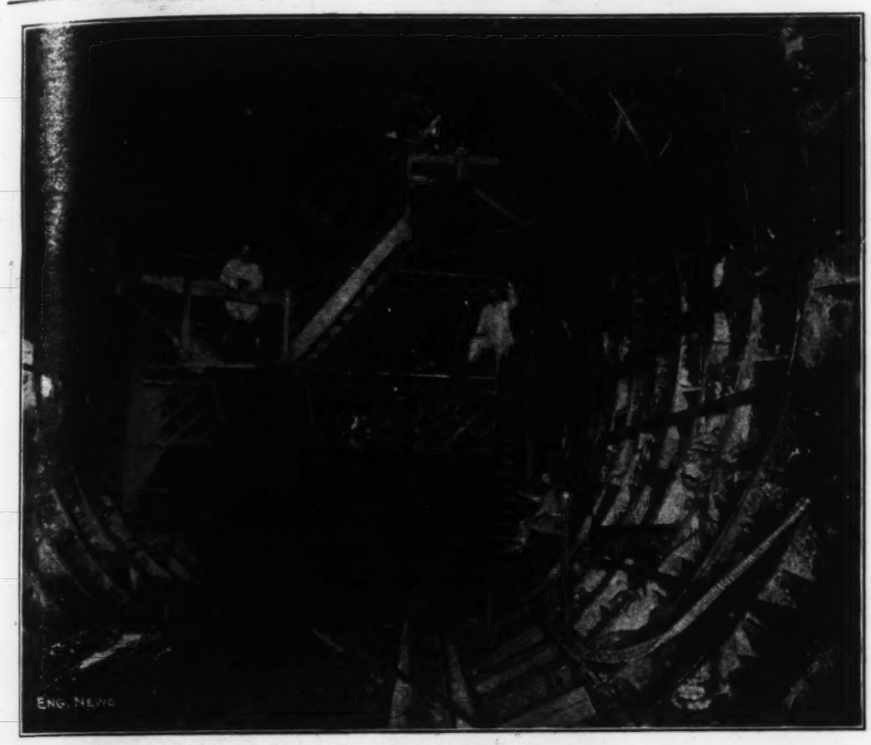


FIG. 13. STEEL TRAVELING STAGE.

TRENT DISTRICT.

GENERATION OF POWER.—Aside from small streams flowing into Lake Ontario, which have not been considered, the sources of hydro-electric power for this district are the Trent and Moira Rivers. On the Upper Trent large developments have been made, and all remaining available power will be needed in the near future for the immediate territory. On the lower Trent the water-powers are much more extensive, and practically undeveloped, the only ones used so far being small stations for paper mills, etc. Of the various power sites on this part of the river, at least five are worthy of being fully developed for long distance transmission. The dry weather capacity of these five would be some 25,600 HP., more than enough to supply, for the present at least, all the demands of the Lake Ontario towns. It would not be necessary to develop all these powers at once, but, as the demand increased, the extensions could be made one by one, all being worked in unison and under one management. This district appears to be one in which united management with one transmission system would be far more economical than if several companies were to take up the various water-powers to develop and transmit energy independently of each other. The estimates are considered quite approximate owing to the likelihood of the Trent Canal modifying designs, and because the field work for these estimates was necessarily meager. It is probable that the estimates on the development are correct within 10%.

TRANSMISSION.—Taking as a present source of power Healy's Falls, with auxiliary development at Middle and Rauney's Falls, roughly, two and six miles below Healy's Falls, a development and transmission scheme has been worked out supplying power to all of the Lake towns from Whitley to Kingston. A private right-of-way is provided for in the estimates, 66 ft. wide from Healy's Falls to Brighton, and of varying width along the Grand Trunk Ry., east and west. Double-circuit steel towers are to be provided from the power-house to Brighton, single circuit steel towers from Brighton to Deseronto Junction, and high-class wood-pole construction to Kingston. The general transmission scheme involves 3-phase, 25-cycle current at 55,000 to 60,000 volts. Municipal distributing circuits have been arranged for 2,200 volts. Entire capital and operating charges are included in the price of power.

LAKE HURON AND GEORGIAN BAY DISTRICT.

GENERATION OF POWER.—In the southern inland portion of this district water-powers are either very limited in extent or entirely absent, as the rivers all flow from a high table-land, lacking in storage, through a well-cleared country without important declivities. It is only near the mouths of rivers in this portion of the district that water-powers of any extent are met with. Further northward, however, the Severn, Muskoka, Maganetawan, French, Sturgeon and Wahnapitae Rivers have entirely different characteristics, with their sources abounding in lakes and still practically in virgin forest, so that the water-powers on these rivers are extensive and valuable, and have already been developed to a considerable extent. At the present time there is a large number of small local developments providing electric light and small amounts of power to local consumers.

In this district 60-cycle frequency has been chosen for developments estimated upon, owing to the fact that a considerable number of installations are already operating at 60 cycles, and that this is, for lighting purposes, the frequency usually adopted; further, in that section of the district where electric railways are probable, and for which low frequency is desirable, the supply of hydraulic power will be altogether required for other purposes, such as lighting and small motor loads.

TABLE I.—ESTIMATED COSTS OF HYDRO-ELECTRIC POWER THROUGHOUT THE PROVINCE OF ONTARIO.

Municipality.	Source of power.	Present power used. Total.	Portion admitting electrical installat'n.	Future load estimated HP.	Proposed. Total investment.	Investment per HP.	Distance of transmission, miles.	Annual charges per HP. Generation.	Transmission.	Step-down transformation.	Administration.	Interswitching.	Total cost 24-hr. power.
NIAGARA DISTRICT:													
Population.	Niagara Falls Companies												
Hamilton & Dundas. 57,500		18,473	12,800	16,000	.....	.....	46	12.69*	0.90	1.56	0.14	0.07	15.36
Toronto 250,000		53,360	40,200	50,250	.....	.....	88	13.08*	1.86	1.36	0.16	0.07	16.53
Georgetown 1,400		1,450	720	900	.....	.....	77	13.30*	3.03	3.00	0.50	0.31	20.14
Milton 1,600		500	430	537	.....	.....	66	13.30*	2.08	3.70	0.50	0.31	19.89
TRENT DISTRICT:													
	Healy's Falls, 8,000 HP.	.....	.....	.....	$675,000	$84.38	...						
Kingston 19,400		2,600	2,200	2,750	.....	.....	98	13.50	5.42	2.12	0.36	0.03	21.43
Belleville 10,200		2,065	3,600	4,500	.....	.....	50	12.87	1.71	1.69	0.36	0.03	16.66
Oshawa 4,920		1,640	1,460	1,825	.....	.....	85	13.35	5.51	2.27	0.36	0.03	21.52
Whitby 2,250		380	250	312	.....	.....	90	13.52	8.82	4.60	0.36	0.03	27.33
LAKE HURON AND GEORGIAN BAY DISTRICT:													
	Maitland River, 1,600 HP.	.....	.....	.....	325,000	203.12	...						
Goderich 4,300		1,450	500	625	.....	.....	4	14.12	1.57	....	0.75	....	16.44
Clinton 2,800		2,800	200	250	.....	.....	9	16.83	4.59	4.30	0.75	....	26.47
Mitchell 2,200		2,200	200	250	.....	.....	29	16.83	4.59	4.30	0.75	....	26.47
	Beaver and Severn Rivers 2,267 and 4,000 HP.	.....	.....	.....	291,000	128.28	...						
		.....	.....	.....	350,000	87.50	...						
Owen Sound 10,000		3,750	2,000	2,500	.....	.....	89	12.90	4.14	2.12	0.91	0.15	20.22
Collingwood 7,000		1,650	1,000	1,250	.....	.....	53	12.95	5.30	2.65	0.91	0.15	21.96
Victoria Harbor.... 400		600	Indefinite	400	.....	.....	17	12.70	1.09	3.78	0.91	0.15	18.63
OTTAWA VALLEY AND ST. LAWRENCE RIVER DISTRICT:													
	Iroquois, 1,200 HP.	.....	.....	.....	179,000	149.16	...						
Brockville 9,000		700	700	875	.....	.....	27	22.50	5.07	1.64	3.34	....	32.55
Prescott 3,035		215	215	208	.....	.....	15	21.97	2.57	4.69	3.19	....	32.42
	High Falls, Miss'ippi River Scheme A, 2,400 HP.	.....	.....	.....	195,000	81.25	...						
Brockville 9,000		700	700	875	.....	.....	63	12.13	7.27	2.30	3.98	....	25.68
Prescott 3,035		215	215	208	.....	.....	75	12.13	16.10	4.38	3.97	....	36.58
Smith's Falls..... 5,700		815	300	504	.....	.....	35	11.54	2.95	3.88	3.83	....	22.20
Perth 4,000		240	150	210	.....	.....	23	11.27	1.76	5.75	3.73	....	22.51
	High Falls, Miss'ippi River Scheme B, 1,100 HP.	.....	.....	.....	123,000	111.82	...						
Smith's Falls..... 5,700		815	300	504	.....	.....	35	16.00	6.42	3.00	4.93	....	30.45
Perth 4,000		240	150	210	.....	.....	23	15.55	3.72	5.00	4.79	....	29.16
	Fountain Falls, Montreal River, 2,400 HP.	.....	.....	.....	214,000	89.16	...						
Cobalt .....Indefinite		1,800	1,400	2,800	.....	.....	15	18.30	1.64	1.73	2.50	....	24.17†
Kerr Lake.....Indefinite		1,000	800	1,600	.....	.....	12	18.22	1.24	2.35	2.48	....	24.29†
Haileybury 1,215		200	200	400	.....	.....	20	18.52	5.37	5.21	2.54	....	31.64†
ALGOMA, THUNDER BAY AND RAINY RIVER DISTRICT:													
	Dog Lake, 13,675 HP.	.....	.....	.....	834,100	61.00	...						
Port Arthur..... 10,200		.....	.....	13,382	.....	.....	25	6.41	0.92	1.21	0.56	....	9.10
	Cameron Rapids, 16,350 HP.	.....	.....	.....	817,500	50.00	...						
Port Arthur..... 10,200		.....	.....	13,382	.....	.....	75	5.91	2.16	1.19	0.49	....	9.75
	Slate Falls, 3,686 HP.	.....	.....	.....	357,600	97.00	...						
Bruce Mines..... 980		.....	.....	3,300	.....	.....	26	9.66	1.67	2.96	0.43	....	14.72
Thessalon 1,350		.....	.....	150	.....	.....	16	9.67	1.03	15.96	0.44	....	27.10

*Based on price of $12 per HP. per annum at High Tension Bus Bars Transformer Station, Niagara Falls.
†Based on capacity equal to portion admitting electrical installation.

TABLE II.—PRESENT RATES FOR ELECTRIC POWER IN ONTARIO. (Spring, 1906, to Spring, 1907.)

Municipality.	Street arcs per lamp per year.	Commercial Incdst. per KW.-hr. metered, net.	Residence Incdst. per KW.-hr. metered, net.	Average HP. used. Flat rate.
NIAGARA DISTRICT:				
Hamilton	$84.00[1]	$0.15	$0.10	$90 to $30[2]
Toronto	69.35[1]	.12	.08	$180 to $51[3]
TRENT DISTRICT:				Metered, 8c.
Kingston	60.00[4]	.12½	.12½	per KW.-hr.
Belleville	58.00	.10	.08	$30
Oshawa	65.00[4]	8½ to 15	8½ to 15	...
Whitby	36.00[5]	.10	.10	...
LAKE HURON AND GEORGIAN BAY DISTRICT:				
Goderich	40.00	.09	.09	...
Owen Sound	51.00[4]	.07½	.07½	...
Collingwood	60.00	7 to 10	7 to 10	...
OTTAWA VALLEY AND ST. LAWRENCE RIVER DISTRICT.				
Brockville	62.25	10 & 14	10 & 14	...
Prescott	.....	.10	.10	...
Smith's Falls	56.25	.08	1.85[6]	$20
Perth	65.00	3.00[6]	2.00[6]	...
ALGOMA, THUNDER BAY AND RAINY RIVER DISTRICT:				
Port Arthur	.....	6 to 10-15%	7 to 10-10%	...
Bruce Mines	.....	$3 to $6[3]	$3 to $6[3]	...
Thessalon	76.00	$3.00[6]	$3.00[6]	...

[1]All night, every night. [2]Inversely according to amount; these figures are for 0.4 and 12 HP., respectively. [3]Inversely according to amount; these figures are for 0.4 and 30 HP., respectively. [4]Moonlight schedule, all night. [5]Municipal plant. [6]To midnight, moonlight schedule. [7]To midnight, every night. [8]Flat rate per 16-c. p. lamp per year.

A careful study has been made of the present probable demands for electric power in relation to possible water-power developments capable of supplying these demands, and five developments have appeared to be worthy of serious consideration, namely: (1) On the Maitland River near Goderich, 80-ft. head; (2) on the Saugeen River, at Southampton, 40-ft. head; (3) Eugenia Falls, on the Beaver River, 420-ft. head; (4) Big Chute, on the Severn River, 52-ft. head; and (5) on the South River near Nipissing, 85-ft. head. The capital cost in each case includes step-up transformer stations, one reserve generating unit in excess of each of the above-mentioned capacities, and a spare transformer in each station.

TRANSMISSION OF POWER.—The supply of power to Goderich, Clinton, Seaforth and Mitchell is contemplated from the development on the Maitland River. The scheme outlined involves transmission at generator voltage (2,200 volts, 60-cycle) to Goderich, but stepping up to 22,000 volts for transmission to Clinton, Seaforth and Mitchell. A high-class wooden pole line upon the highways, with telephone wires upon the same poles, is considered as suitable for such a distance.

DISTRIBUTION OF POWER.—The cost of distribution from the municipal sub-stations to the consumers' premises varies widely with different conditions, and depends upon the distances involved, the magnitude of the demands of individual consumers and the grouping of these consumers.

OTTAWA VALLEY AND ST. LAWRENCE RIVER DISTRICT.

SOURCES OF HYDRO-ELECTRIC POWER.—In certain portions of this District, there are very large powers, for which there is no apparent available market existing. Such are many of those on the Ottawa, Madawaska and Petawawa Rivers. Westward from the Rideau, which joins the Ottawa River at Ottawa, all the tributaries of the latter come from basins containing a large number of lakes and marshes, and have a highly uniform flow. The differences of elevation along these streams are all considerable. Of the water-powers in this District, those of the St. Lawrence and of the Ottawa Rivers are the largest, and for the entire development of a water-power on either a complete damming of a great river bed is necessary.

The St. Lawrence being a navigable stream throughout, and, at points of possible development by the Province of Ontario, an international stream, it is not at present necessary to consider here the question of making use of these water-powers in this manner. Canals paralleling each of the rapids of the St. Lawrence have been built by the Dominion of Canada, thereby concentrating at one or more points the existing heads and providing to a limited extent water supply, which has been, in whole or in part, utilized in nearly every case by private interests. The Ottawa River over a considerable portion of its course is a navigable stream, and its waters are, moreover, interprovincial. This latter fact need not stand in the way of the intelligent and economical development of the water-powers, although it has led to difficulties in the past. Estimates of power are based on the entire low water flow of the stream at each important fall or rapid. The construction of a 23-ft. Georgian Bay Ship Canal, as is proposed, would altogether alter the profile of the Mattawa and Ottawa Rivers, and would concentrate the entire fall of these rivers at the various necessary dams. A further result would be the reduction of the variation in the discharge of these rivers, an end desirable for canal operations as reducing the seriousness of the annual floods. Essential to such control of floods would be the damming of Lake Temiskaming and other lakes in the upper Ottawa valley. An example of the effect of canalization and storage of flood waters may be noticed in the case of the Rideau River, the existence of whose dams and retaining works causes the discharge of the stream to be more than ordinarily regular.

TABLE III.—Capital Cists and Annual Charges on Motor Installations, Polyphase, 60-Cycle Induction Motors.

Capacity. HP.	Capital cost per HP. installed.	Annual charges—Interest 5%	Depreciation and repairs 6%	Oil, care and operation.	Total per HP. per Annum.
5	$39.00	$1.95	$2.34	$4.00	$8.29
10	36.00	1.80	2.16	3.00	6.96
15	30.00	1.50	1.80	2.50	5.80
25	25.00	1.25	1.50	2.00	4.75
35	22.00	1.10	1.32	1.75	4.17
50	20.00	1.00	1.20	1.50	3.70
75	19.00	.95	1.14	1.25	3.34
100	17.00	.85	1.02	1.00	2.87
150	15.00	.75	.90	.80	2.45
200	14.00	.70	.84	.70	2.24

By combining the costs given in this table with the cost of distributed power, as indicated in Table I., the final or total charge per HP. per year will be obtained.

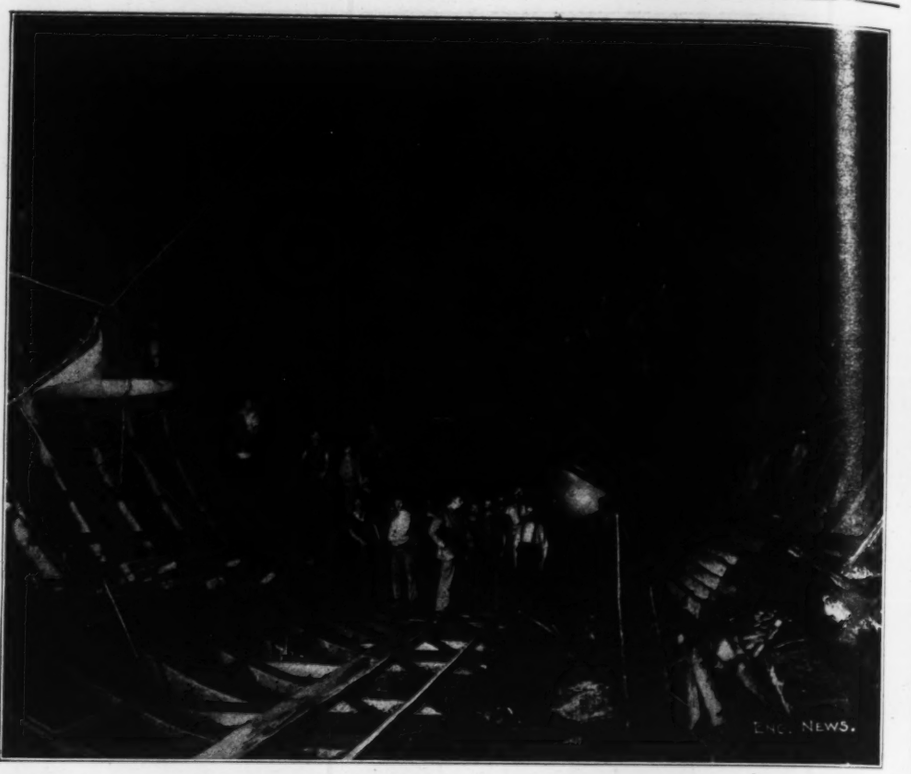


FIG. 14. STAGE FOR BOLTING AND CALKING THE LINING OF THE ROTHERHITHE TUNNEL (27 FT. 8 INS. DIAMETER INSIDE OF FLANGES.)

present in operation on the Spanish River, furnishing power for pulp mills and mines. This district contains valuable timber and mineral areas, factors which will in the near future have an important bearing in determining the economic value of the available water-powers. At the head of Lake Huron is the important international power of the Sault Rapids, on the St. Mary's River, which takes the total run-off of the Lake Superior basin. This power is partially developed on both sides of the river, and forms the basis of operation for the industries established and controlled by the Lake Superior Corporation at Sault Ste. Marie. Along

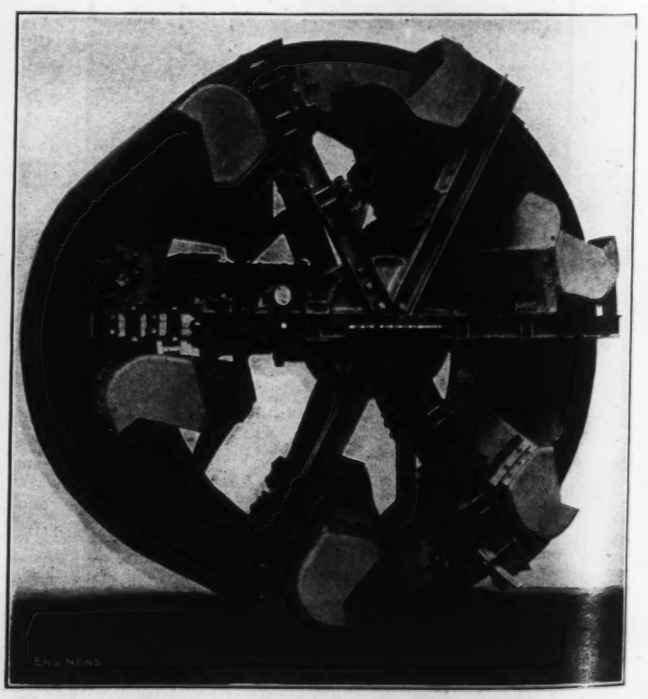


FIG. 15. FACE OF EXCAVATING MACHINE USED IN DRIVING THE PILOT TUNNEL (12 FT. 6 INS. DIAMETER) OF THE ROTHERHITHE TUNNEL.

ALGOMA, THUNDER BAY AND RAINY RIVER DISTRICTS.

GENERATION OF POWER.—Of the rivers flowing into Lake Huron along the north shore, the Spanish, Vermilion and Mississauga are the most important as regards size and hydro-electric possibilities, numerous water-powers admitting of more or less economical development existing on these rivers. Two plants are at

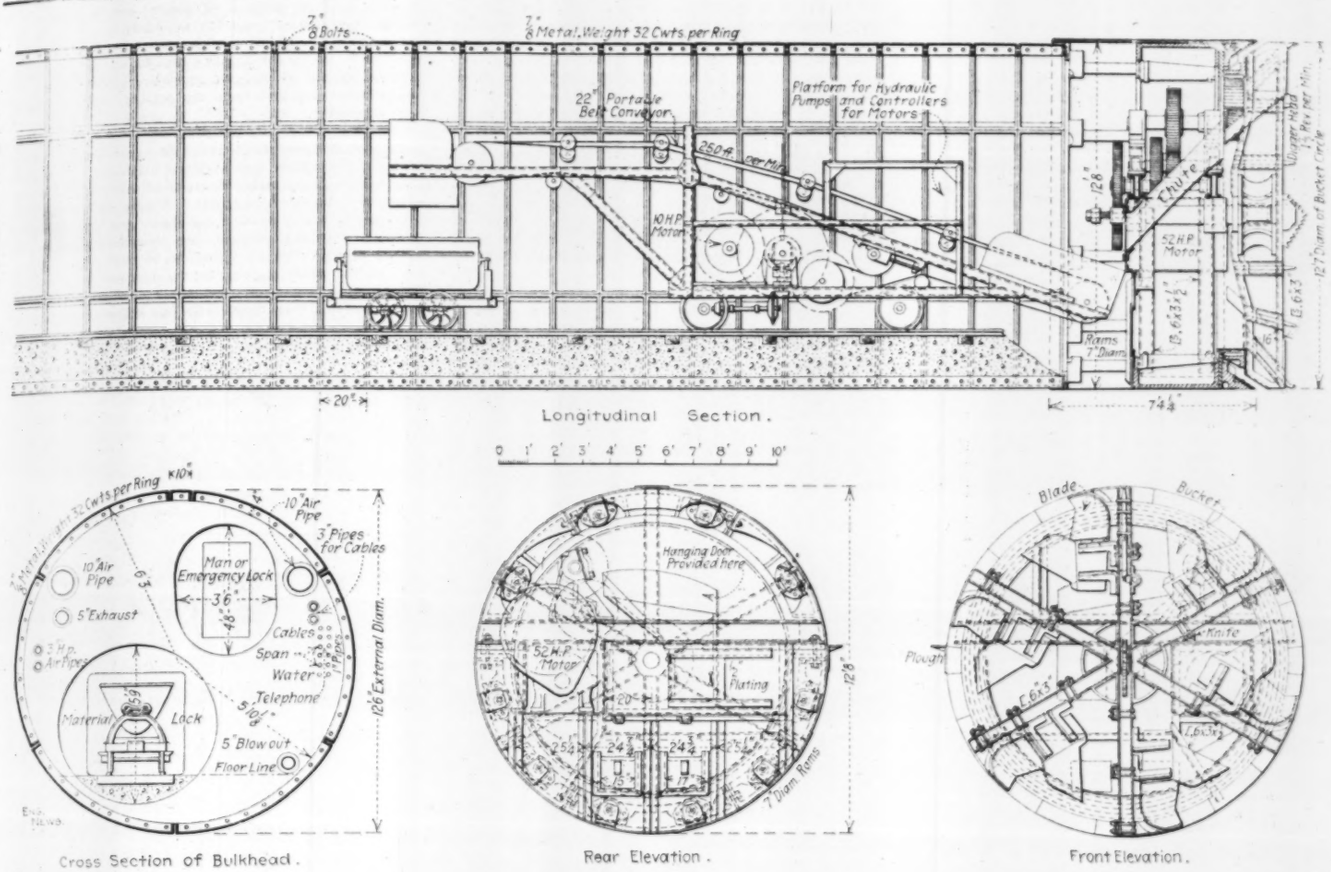


FIG. 16. SHIELD AND EXCAVATING MACHINE FOR PILOT TUNNEL.

the north shore of Lake Superior, many fine water powers exist, which, in many cases have but little present economic value; exceptions being the Nepigon, Kaministiquia and Current Rivers, the importance of which is due to the fact that they are within transmission distance of the rapidly increasing power markets of Fort William and Port Arthur, and, especially in the case of the Nepigon, are of sufficient extent to use for grinding the pulp output of the Nepigon watershed.

In practically all cases enough local pondage can be obtained above the headworks to provide for a considerably increased peak capacity. It is not generally feasible, however, to obtain in this way storage sufficient to materially augment the natural dry-weather flow over a greater period than that required to take care of the daily variation of load demands, without a large rela-

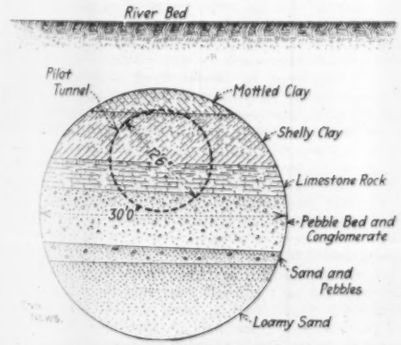


Fig. 17. Section Showing Strata Penetrated by the Rotherhithe Tunnel.

tive expenditure for impounding storage reservoirs. There are two notable exceptions, namely, Lake Nepigon, with 1,500 sq. mi. of area, and Dog and Shebandowan Lakes, with 100 sq. mi. of area, serving to create natural storages, which, in the case of Dog Lake, can be enormously increased in value by the expenditure of a small sum for construction of a dam at the outlet of the lake, which will raise the lake level 10 to 15 ft. during high-water and hold the same for use when required at low-water periods.

Three development schemes have been studied: (1) Dog Lake Development: This power is situated about 25 miles northwest of the towns of Port Arthur and Fort William. An effective head of 310 ft. can be obtained by utilizing the difference in level between Big Dog and Little Dog Lake. The distinguishing feature of the development would be the construction of about 3,500 ft. of head-water tunnel. The value of this power is due to the high head and the exceptionally good storage facilities of Dog Lake, which has an area of 53 sq. mi. (2) Cameron Rapids Development: This power is situated on the Nepigon River, about 14 mi. north of Nepigon Station. The very considerable economic importance of this power is due to the fact, already mentioned, that it is within transmission distance of Port Arthur and Fort William, and that it is available for the development of the extensive pulpwood areas of the Nepigon watershed. In addition to this, the remarkably

TABLE IV.—Capital Costs of Steam Power Plants and Annual Costs of Power per B. HP.

Size of plant, HP.	Capital cost of plant per HP. installed. Engines, Boilers, etc. installed.	Buildings.	Total.	Annual cost of 10-hr. power per B. HP.	Annual cost of 24-hr. power per B. HP.
Class I.—Engines: Simple, slide valve, non-condensing. Boilers: Return tubular.					
10	$66.00	$40.00	$106.00	$91.16	$180.76
20	56.00	37.00	93.00	76.31	151.48
30	48.70	35.00	83.70	66.46	131.68
40	44.75	33.50	78.25	59.49	117.74
50	43.00	31.00	74.00	53.95	106.46
Class II.—Engines: Simple, Corliss, non-condensing. Boilers: Return tubular.					
30	70.70	35.00	105.70	61.14	117.70
40	62.85	33.50	96.35	55.50	107.10
50	59.00	31.00	90.00	50.70	97.73
60	56.00	30.00	86.70	47.42	91.34
80	50.00	27.50	77.50	43.86	85.41
100	44.60	25.00	69.60	40.55	79.19
Class III.—Engines: Compound, Corliss, condensing. Boilers: Return tubular, with reserve capacity.					
100	63.40	28.00	91.40	33.18	60.05
150	53.70	24.00	77.70	29.83	54.63
200	50.10	20.00	70.10	28.14	51.72
300	45.90	18.00	63.90	26.27	48.83
400	43.55	16.00	59.55	24.84	46.12
500	41.25	14.00	55.25	23.73	44.21
750	40.50	13.00	53.50	23.56	44.02
1,000	39.00	12.00	51.00	23.26	43.71
Class IV.—Engines: Compound, Corliss, condensing. Boilers: Water-tube, with reserve capacity.					
300	55.20	18.00	73.20	25.77	46.32
400	51.50	16.00	67.50	24.18	43.61
500	49.40	14.00	63.40	23.19	42.03
750	46.80	13.00	59.70	22.88	41.56
1,000	44.30	12.00	56.80	22.47	41.11

TABLE V.—Producer Gas Power, Showing Capital Costs of Producer-Gas Plants Installed, and Annual Costs of Power per Brake Horse-Power.

Size of plant, HP.	Capital cost of plant per HP. installed. Machinery, etc.	Buildings.	Total.	Annual cost of 10-hr. power per B. HP.	Annual cost of 24-hr. power per B. HP.
10	$137.00	$40.00	$177.00	$53.48	$90.02
20	110.00	36.00	146.00	44.47	75.22
30	93.00	33.00	126.00	38.73	65.99
40	84.50	29.00	113.50	35.05	59.85
50	80.00	26.00	106.00	32.27	55.22
60	79.00	24.00	103.00	30.49	52.03
80	78.20	22.00	100.20	28.70	48.95
100	77.50	20.00	97.50	27.05	45.40
150	76.00	19.00	95.00	25.87	43.17
200	74.00	17.00	91.00	24.95	41.78
300	73.00	16.00	89.00	24.24	40.40
400	71.50	14.00	85.50	23.41	39.03
500	70.00	12.00	82.00	22.54	37.54
750	67.50	10.00	77.50	21.55	35.99
1,000	65.00	8.00	73.00	20.46	34.66

TABLE VI.—Showing the Effect on the Cost of Power of a Variation in the Price of Coal of 50 Cents per Ton.

Size of plant, HP.	Suction producer-gas 10-hr.	Suction producer-gas 24-hr.		Steam 10-hr.	Steam 24-hr.
10	$1.15	$2.53	Simple	$6.14	$13.47
20	1.13	2.46	side valve	5.25	11.56
30	1.10	2.40	engine.	4.71	10.35
40	1.07	2.33		3.56	7.84
50	1.04	2.29	Simple auto-	3.37	7.41
60	1.01	2.24	matic non-	3.26	7.16
80	.98	2.18	condensing.	3.15	6.97
100	.96	2.12		3.12	6.87
150	.94	2.07		1.75	3.85
200	.92	2.02	Compound	1.69	3.71
300	.90	1.98	Condensing.	1.62	3.60
400	.88	1.94		1.56	3.44
500	.86	1.89	Compound con-	1.39	3.05
750	.82	1.81	densing; water	1.39	3.05
1,000	.76	1.72	tube boilers.	1.39	3.05

favorable topographical conditions in the neighborhood of the power site, and the magnificent storage facilities offered by Lake Nepigon, with its 1,500 sq. mi. of area, which would obviate all necessity for artificial regulation for some time to some, combine to make this a most attractive proposition from an engineering standpoint. (3) Slate Falls Development: This power is situated on the Mississauga River, about 25 mi. from the town of Bruce Mines. A head of 40 ft. can be obtained here, and in view of the natural conditions, the scheme of development is simple. No natural storage basins are available in the vicinity, but the dam necessary for the development will provide storage sufficient for any daily peak load within the limit of the temporary overload capacity.

TRANSMISSION OF POWER.—In all cases, the use of a high-class wood pole has been assumed, with telephone wires on the same poles.

THE TESTING OF IRRIGATION PUMPING PLANTS.

During the summer of 1905, by the cooperation of the Office of Experiment Stations, United States Department of Agriculture, and the State of California the testing of pumping plants to determine the actual cost of pumping water, for irrigation, by various methods and under various conditions. The work was entirely in the field and carried out near Pomona and Riverside in southern California and in the reclamation districts of the lower Sacramento River.

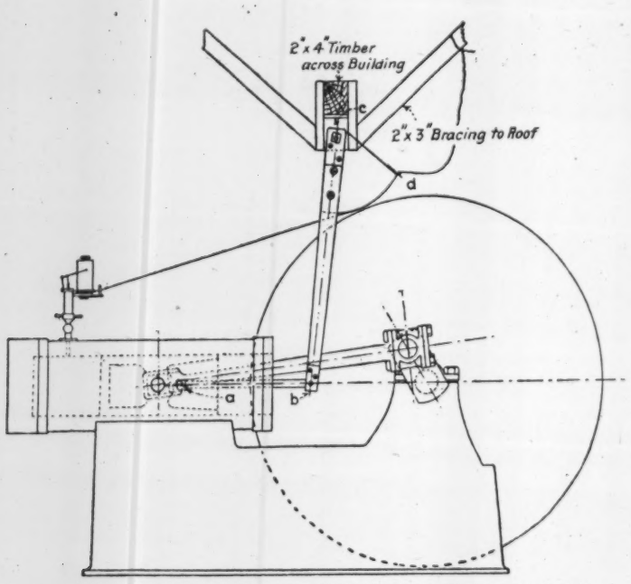


FIG 1. GENERAL ARRANGEMENT. REDUCING MOTION FOR GASOLENE ENGINE INDICATORS.

The field work was considered inclusive enough to serve as a basis for establishing a convenient and satisfactory system. For the instruction of persons desiring to make similar tests the methods and results have been published as Bulletin 181, Office of Experiment Stations. Copies may be obtained from the Department of Agriculture, Washington, D. C. The following extracts from this bulletin have been arranged so as to show the main features and general results of the work as presented therein.

The field work included two classes of tests. The first class consisted of complete tests or those as nearly complete as the conditions of operation would permit. These required measurement of the power developed, either by means of the engine indicator or by indicating wattmeters, a continuous record of the lift, a measurement of the water by means of a weir and a measurement of the fuel consumed. The second class consisted of partial tests where no measurement of power was attempted but merely a measurement of fuel (or electrical energy), water and lift for the purpose of determining the cost of pumping water. Throughout the season's work particular efforts were made to obtain the cost of installation and operation in order to estimate the fixed charges and labor items which constitute so large a portion of running expenses.

MEASUREMENT OF FUEL.—Gasoline for small engines is usually contained in cylindrical tanks at some distance from the pump house and piped to the engine. In such cases the position of the surface of the oil is taken with a small hook gage, consisting of a sharpened piece of wire bent into the form of a hook and fastened to the end of a stick. The surface is noted at the beginning and end of the test by marks made on the stick with the blade of a penknife. The distance between these marks should be measured with a fine scale, and from this and the dimensions of the tank the volume of the gasoline is computed. It is of particular importance to make this measurement every hour in order that an accidental change in the running conditions, or an error, shall not destroy an otherwise good test. When the tank is irregular in cross section or when, though cylindrical, the axis is horizontal, the surface is noted at the beginning of the test as before and at the end of the test the engine is shut down at once. Weighed quantities of gasoline are then poured into the tank until the level returns to the original mark, and the total weight consumed is known. A tested spring balance weighing up to 20 lbs. is convenient for this work. Crude oil used for steam boilers can be measured in the same way unless the area of the containing tank is too great to make an appreciable fall in the surface during the test. In this case (and in all cases where possible) the oil should be weighed out. The pipe leading from the tank to the boiler should be cut and the burners made to draw their supply from a barrel on the floor of the station. This in turn is replenished from time to time from a second barrel on a platform scale. This second barrel is filled either directly by gravity from the oil tank or by a hand pump from the same source of supply. In this way weighed quantities of oil can be poured into the first barrel but care should be taken that the level of the oil in this latter is the same at the beginning and end of the test. In all cases the density of the gasoline, or oil, should be taken on a hydrometer so that weight can be reduced to gallons.

MEASUREMENT OF POWER.—Measurement of the indicated horse-power of a gas engine is the most difficult of all measurements to make in the field. It was found that all ready-made reducing motions, or reducing wheels, are unsatisfactory when used on the ordinary gas engine and that the pendulum-reducing motion gives the best results. The following is a description of the device used: In nearly all gas engines there will be found a set screw at "a" (Fig. 1), which serves to hold the wrist pin in the piston and prevent it from turning. In many engines there are two of these. This set screw is removed and another inserted which has a slotted head, as at "a" (Fig. 2). Several of these should be kept on hand to correspond with the standard sizes of set screws—that is, ½, ⅝, ¾, etc. This slotted set screw is set into the piston with the slot vertical. A number of flat links are then made with lengths varying from 14 to 28 ins., and about $^3/_{16} \times ^3/_4$-in. in cross section. The longer ones may be made heavier, say, ¼ × 1 in., but the ends must be brought down to $^3/_{16}$-in. in thickness to fit the slots in the set screws. The link is chosen which corresponds to the stroke of the particular engine under test, and one end is fastened into the slotted set screw by a $^3/_{16}$-in. split pin. A lever or pendulum is then constructed of light strong wood as shown in Fig. 2. The lower end is protected with ⅛-in. iron plate, as shown, so as to receive the other end "b" of the link, and this latter is secured thereto with a small bolt. At the upper end of the pendulum there is fastened by a couple of wood screws a sector whose radius corresponds to the stroke of the engine under test, and both sides are protected with ⅛-in. iron plate. The whole is hung from an iron pin containing a shoulder as shown at "c" (Fig. 2). A couple of jam nuts prevent the pendulum from slipping off the pin, which is passed through a wooden block nailed to a timber which spans the pump-house above the engine at right angles to the line of connection. This timber should be braced from the roof or sides of the building. The pendulum is so adjusted that it hangs vertical with the piston at mid stroke and with the link a—b horizontal. A groove is cut on the perimeter of the circular sector, and a piece of metal with a V-shaped notch at "d" (Fig. 2) engages a knot on the indicator card, so that the indicator can be hooked up or unhooked without difficulty. Care should be taken that the whole apparatus is well constructed, so that no breakdown may occur when running at high speed. Where engines are "short connected" no great error is caused by allowing the end b of the pendulum to override the crank at its extreme outward throw. Of course only such [illegible] can be indicated as have the necessary opening [illegible] indicator plug or some opening into the [illegible] chamber to which the indicator can be attached [illegible] piping. Nearly all steam engines are already [illegible] the indicator and with them the ordinary reduc[illegible] may be used.

In taking cards on a gasoline engine it h[illegible] custom to take a number on the same sh[illegible] to ten. Successive cycles in such engines [illegible] identical so that a series of cycles is necessary [illegible] average indicated horsepower. Where the [illegible] very nearly alike, so that the lines run clos[illegible] and blur into one another, the planimeter ca[illegible] by eye through the mean position of such lines [illegible] the cycles differ widely the planimeter can [illegible] around each separately and the set averaged [illegible] way. A single cycle taken with the indicator on [illegible] line engine is of little use in computing hors[illegible] power. The indicated horsepower is computed by the [illegible] nary formula:

$$\text{I. HP.} = \frac{\text{P. L. A. N.}}{33{,}000},$$

in which,
P = mean effective pressure in lbs. per sq.
L = length of stroke in ft.
A = effective area of piston in sq. ins.
N = number of effective strokes per min.

For measuring electric power the indicating w[illegible]meter is used. E. HP. is computed by dividing KW. [illegible] 746.

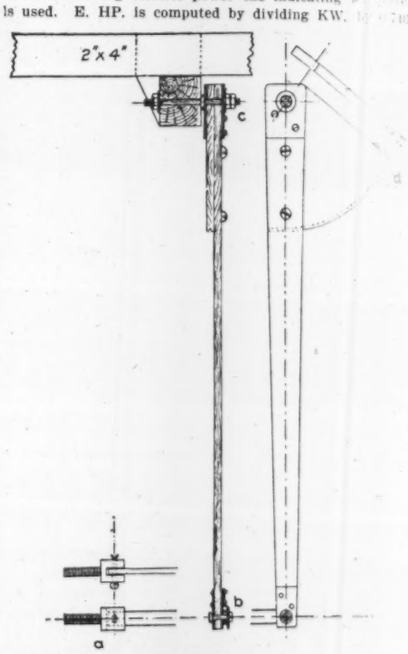


Fig. 2. Details of Reducing Motion for Gasolene Engine Indicators.

MEASUREMENT OF LIFT.—Few pumps are so arranged that it is convenient to attach pressure and vacuum gages and thus obtain the actual head worked against by the pump. In deep-well, air lift and centrifugal pumps running under water it is practically impossible to use gages, and so few plants were found where gages could be properly applied that the attempt to get the working head by this method was abandoned and the measured or leveled head was used instead. This is obtained by measuring with a tape the vertical distance from the surface of the water in the sump or in the well casing to the center of the final discharge. When the pump runs under water in an open pit or when the suction draws from a ditch or stream this is most easily done by attaching a float to the end of the tape and lowering it until it touches the water. When the level of the water falls so as to be below the top of the casing of a bored well or in an air well the measurement is more difficult. Where there is sufficient space between the well casing and the suction pipe, say 1½ ins., a small float may be lowered to the water level if the well is bored straight. A long rubber tube, open at both ends, is sometimes used for determining water levels in wells. By weighting one end the tube can be lowered into a very narrow space and the water level can be determined by blowing through the tube with a steady pressure. However, the crookedness of the well casing and the sleeves on the suction pipe may prevent the lowering of the tube. A dry steel tape may be lowered into the well and withdrawn, the wet portion indicating the water level. The difficulty here is that the wet sides of the well casing and suction pipe may give false indication and it entirely fails if water is draining from the pit into the well. With all the different methods tried several instances were

found where it was impossible to measure with certainty the depth to water. Since the actual head pumped against is valuable information for the irrigator himself the writer proposes the following arrangement, which, if installed when the plant is erected, would furnish an easy and certain method of determining the lift. When the pump or suction pipe is first lowered into the well let a small pipe, of say ⅝ or ½-in. diam., be lowered with it. This can be secured to the sides of the suction pipe at intervals and should reach within a foot or so of its lower end. Its length must be carefully measured before lowering. The upper end should be connected to a receiver of about 1 cu. ft. capacity and an accurate pressure gage attached to this latter. Air can be forced into this receiver with a small bicycle pump, or if the engine be so arranged as to start by compressed air this can be used to charge the receiver. The pressure gage will then rise till the air bubbles out of the end of the small pipe but no higher. The supply of compressed air being discontinued the reading of the gage multiplied by 2.3 will give the length of the small pipe submerged, which when subtracted from the total length of the small pipe will give the depth to water. It is evident that a paper dial, graduated so as to read the actual lift on the pump directly, could be substituted for the regular one on the gage.

MEASUREMENT OF WATER.—The discharge was measured in nearly every instance by means of a weir. Many plants in southern California have weirs installed either at the pump-house or somewhere on the pipe line. These usually consist of a concrete box which receives the water from the pump at one end and delivers the water over a weir set in a concrete partition into a second compartment from which the pipe line distributes the water to the orchard. When the pipe line is very long or of too small diameter or has little slope the weir is drowned and rendered useless. The free contractions of most weirs made in this way are interfered with by the concrete of the partition coming too close to the crest and sides of the weir. The box is nearly always too short to permit the use of baffle plates to still the violent commotion produced by the pump discharge. For purposes of testing, an ordinary weir

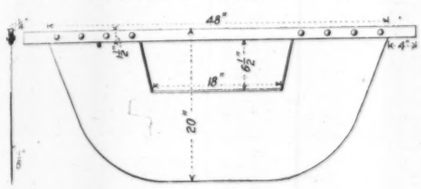


Fig. 3. Portable Steel Weir for Measuring Discharge of Pumps.

board set in an open ditch is vastly better than the majority of permanent weirs found in the ditches tested.

All the results of these measurements have been computed by means of the Francis formula,

$$Q = 3.33\ (b - .2h)\ h^{3/2}$$

that being the basis of most of the weir tables in use by the irrigators and also the one employed by this office in compiling its weir tables.* The writer is certain, however, from his own experiments, as well as from the work of others, that this formula gives results too small for low heads and narrow crests. Francis himself did not intend it to be used for heads under 6 in. and for breadths under 3 ft., yet it has been extended to cover all cases of heads and breadths. A closer approximation to the discharge would probably be reached by using the weir coefficients of Hamilton Smith, Jr.† The same criticism applies to the Cipolletti weir formula as generally used.

The head on the weir was measured by an ordinary rule held on the head of a nail which was previously leveled with the crest of the weir by means of a straightedge and machinist's level. The readings could not be made closer than the nearest one-sixteenth inch.

*U. S. Dept. Agriculture, Office of Experiment Stations, Bulletin 86.

†Hydraulics, by Hamilton Smith, Jr., John Wiley, N. Y.

TABLE I.—BASIS FOR COMPUTING FIXED CHARGES.

	Per cent.
Gasoline engine plants:	
Depreciation	12 to 15
Interest	6
Taxes and insurance	1
Average total	20
Motor-driven plants:	
Depreciation	7 to 9
Interest	6
Taxes and insurance	1
Average total	15
Steam plants of ordinary type:	
Depreciation	9 to 11
Interest	6
Taxes and insurance	1
Average total	17
Highest quality steam plants—average	12

On account of this rather rough method of measurement no closer approximation than the Francis formula was made.

The useful water horse-power of a pump is computed by the following formula:

$$\text{Useful water horse-power} = \frac{Q\ w\ h}{550}\ \text{in which}$$

Q = volume of water pumped in cu. ft. per sec.

w = weight of 1 cu. ft. of water = 62.3 lbs.

h = lift or head through which the water is actually raised, in ft.

MEASUREMENT OF FEED WATER.—Feed water for steam plants was measured, wherever possible, by taking the fall in the level of the feed tank, and in one instance with a Worthington piston meter, already installed in the feed line. For a careful test the water should be weighed out on a platform scale exactly as described for oil measurements. As the amount of feed water handled, however, is more than ten times that of the oil, the apparatus required must be many times larger and more elaborate. Such a method is scarcely applicable to tests of the character of those herein described, especially as the feed water is the least important factor from our point of view.

SUMMARY OF COMPLETE TESTS.

Table I. summarizes the results of 38 tests. For the gasoline-engine and steam-engine driven plants the plant efficiency is the ratio of the useful water horse-power to the indicated horse-power. For the electrically-driven plants, the plant efficiency is the ratio of the useful horse-power to the electrical horse-power. The final relation of fuel consumption to water lifted is ex-

TABLE II.—SUMMARY OF COMPLETE TESTS ON GASOLINE PUMPING PLANTS.

No. of test.	Discharge. Per second. cu. ft.	Discharge. Per minute. gals.	Lift. feet.	Useful water horsepower.	Indicated horsepower.	Plant efficiency. per ct.	Duration of test. h. m.	Gasoline consumed. Total dur-ing test. gals.	Gasoline consumed. Per hour. gals.	Gasoline consumed. Per Indicated HP.-hr. gals.	Gasoline consumed. Per useful water HP.-hr. gals.	Number of hours plant runs per y'r.	Total gasoline used per year. gals.	Cost of gasoline per gal.	Cost per useful water horse-power hour. Gasoline.	Cost per useful water horse-power hour. Attendance and repair.	Cost per useful water horse-power hour. Total.	Cost per acre-foot of water pumped. Gasoline.	Cost per acre-foot of water pumped. Total.
1	....	147	44.4	1.65	5.04	29	1 7	0.87	7.29	0.154	0.527	300	2,190	$0.05½	$0.029	$0.101	$1.364	$1.875	$83.03
2	0.328	301	61.9	4.70	16.3	29	3 10	2.30	7.29	.141	.480	2,000	6,000	.05½	.027	.003	.050	.069	4.27
3	.071	615	94.3	7.00	38.0	20	3 0	5.62	16.88	.148	.741	4,320	24,300	.05	.037	.000	.067	.092	1.05
4	5.94	2,666	11.3	5.94	26.5	34	3 8½	2.95	9.28	.111	.326	496	1,490	.06	.021	.000	.181	.249	24.00
5	.829	372	96.5	9.05	35.2	30	3 0	2.95	11.42	.108	.366	470	1,880	.05½	.029	.000	.157	.216	14.70
6	1.36	611	67.9	10.4	29.3	36	1 0	2.47	2.47	.084	.233	850	2,100	.06½	.022	.000	.071	.098	6.08
7	1.51	678	62.0	10.6	29.7	36	1 0	2.47	2.47	.084	.233	850	2,100	.06½	.022	.000	.071	.098	6.08
8	1.09	489	83.5	11.4	28.7	43	2 0	2.76	11.04	.103	.242	1,800	4,970	.05¾	.033	.000	.104	.137	8.41
9	1.33	597	90.3	13.6	40.8	33	3 30	3 0	14.86	4.25	.312	1,000	4,250	.05	.044	.016	.066	.086	8.58
10	4.96	2,226	55.0	30.9	87.85	35	6 0	6.31	37.85	.100	.204	1,920	12,100	.05½	.012	.005	.022	.038	2.60
11	.241	108	205.5	5.56	16.7	33	2 40	1.63	4.30	.068	.203	750	1,170	.05½	.028	.000	.066	.082	2.60
12	.354	159	180.3	7.23	13.9	52	4 41	1.64	7.70	.118	.227	300	380	.06	.150	.000	.166	.223	3.43
13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
19	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
22	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
34	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
37	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

TABLE IV.—SUMMARY OF COMPLETE TESTS ON STEAM-DRIVEN PUMPING PLANTS.

No. of test.	Discharge. Per second. cu. ft.	Discharge. Per minute. gals.	Lift. feet.	Useful water horsepower.	Indicated horsepower.	Plant efficiency. per ct.	Duration of test. h. m.	Fuel oil consumed. Total dur-ing test. gals.	Fuel oil consumed. Per hour. gals.	Fuel oil consumed. Per Indicated horse-power hr. gals.	Fuel oil consumed. Per useful water HP.-hr. gals.	Number of hours plant runs per y'r.	Total fuel oil consumed per year. bbls.	Cost of fuel oil per bbl.	Rate for contin-gent fixed charges. p. ct.	Total cost of plant.	Cost per useful water horse-power hour. Fuel oil.	Cost per useful water horse-power hour. Attend-ance and repairs.	Cost per useful water horse-power hour. Total.	Cost per acre-foot per-foot. Fuel oil.	Cost per acre-foot per-foot. Total.	Cost per acre-foot of water pumped. Fuel oil.	Cost per acre-foot of water pumped. Total.
25	....	259	164.0	10.7	31.8	34	4 30	122.8	27.3	0.859	2.35	....	....	$0.75	....	$10,000	$0.046	....	....	$0.063	.....	$0.30	.....
26	....	615	94.3	14.7	46	3 0	3 0	63.9	21.3	.672	1.45	....	....	.75	12	55,000	.095	....	....	.095	.....	1.78	.....
27	....	708	213.4	41.3	107.96	38	5 30	185	33.6	.312	.814	4,320	3,400	.75	12	55,000	.043	....	....	.043	.....	3.40	.....
28	....	24,300	13.48	28.7	139	20	3 30	180.4	53.2	.383	6.36	....	....	....	....	....	....	....	....	....	.....	....	.....
29	....	23,350	13.39	78.9	134	59	2 1	109.5	53.8	.324	.755	2,310	4,225	.75	14	33,111	....	....	....	....	.....	....	.....
30	....	405,500	13.59	130.6	....	....	3 30	117.2	35.6	....	4.51	....	....	.82	....	....	....	....	....	....	.....	....	.....
31	....	42,820	9.85	106.4	230	....	3 15	172.5	53.6	.221	.504	....	....	....	....	....	....	....	....	....	.....	....	.....
32	....	39,250	24.74	96.4	117.0	45	3 15	172.5	53.6	.246	.551	....	....	....	....	....	....	....	....	....	.....	....	.....
33	....	1,485	247	91.4	100.6	91	....	....	....	....	....	....	4,000	.50	....	....	....	....	....	....	.....	....	.....
34	....	1,485	247	200.6	217.6	92	6 0	229	38.2	.175	.190	5,000	4,600	1.00	12	55,000	.092	....	....	.092	.....	....	.....
35	....	602	50	7.50	43.9	17	4 12½	84	20.0	.476	2.64	2,000	2,700	.75	14	55,000	.034	....	....	.034	.....	....	.....
36	....	944	87.4	20.8	116.7	18	6 0	109	18.2	.157	.876	2,000	1,200	.75	14	7,500	.022	....	....	.022	.....	....	.....
37	....	2,104	42	22.0	133.7	16	6 51	84.8	14.0	.109	.667	2,000	1,200	.75	14	35,000	.022	....	....	.022	.....	....	.....
38	....	4,62	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	....	.....

TABLE V.—COST COMPARISON: GASOLINE, ELECTRIC AND STEAM POWER PUMPING. SOUTHERN CALIFORNIA TESTS WITH CENTRIFUGAL PUMPS.

Pumping Cost Alone.

Amount water raised.	Motive power.	Cost.
1 ft.-acre-ft.	gasoline	1.5 to 5.0 cts.
"	electricity	4.5 to 10.
"	steam (oil fuel)	1.5 upwards.

Total Cost, Including Attendance and Maintenance.

1 ft.-acre-ft.	gasoline	4.0 upwards.
"	electricity	7.0 to 16.0.
"	steam (oil fuel)	4.0 upwards.

pressed as the number of gallons of oil or the number of KW.-hrs. required per useful water HP.-hr. In reducing this to actual cost the price paid by the pump owner per gallon of gasoline, per barrel of crude oil or per KW.-hr. has been used. The number of hours which each plant runs per year, the cost of the plant, and the cost of attendance and repairs have each been obtained as accurately as possible. From the nature of the case these items are somewhat uncertain. The rate of depreciation of pumping plants varies through an enormous range, being determined largely by the skill and care of the attendant. Many plants are not insured at all. Averaging all conditions found, Table I. appears to be a fair estimate of the rates suitable for use in computing the fixed charges of the various types of plants.

In the case of the larger steam plants that per cent. has been chosen for each individual case which seemed suitable to the special conditions of the plant. These percentages are applied to the first cost of the entire pumping station, including the cost of wells. The latter of course varies greatly with the depth of the wells.

The item of labor is also a difficult one to estimate. Some plants employ an engineer during the whole year, and others only during the pumping season. Others have one man to look after several plants and many plants have no attention whatever.

GASOLINE PLANTS.—The following table summarizes the results of the test of pumping plants using gasoline engines:

Tests numbered 1 to 9 are of gasoline engines running centrifugal pumps. They are arranged in order of the amount of the useful water horse-power, beginning with the smallest. Tests 10 and 11 are of gasoline engines running deep-well pumps. This table covers a wide range and includes within its limits the majority of gasoline power pumping plants in use for irrigation in California.

The plant efficiency varies irregularly. It depends somewhat upon the condition of the gasoline engine, but probably chiefly upon the arrangement and condition of the pump and piping. All turns and obstructions in the piping, any variation in speed of the pump from the speed most suitable to the discharge and lift, any great length of discharge pipe, all tend to reduce seriously the plant efficiency. To secure the best results the size and speed of both pump and engine and all the connections and piping should be carefully planned for the special conditions under which the plant is to operate. In general the results indicate that the plant efficiency should vary from about 30% for the smaller plants to about 50% for the largest plants.

The plant efficiency in deep-well pumps in general may probably be expected to surpass the efficiency of centrifugal pumps, although the two tests, Nos. 10 and 11 in this series, are scarcely sufficient to prove the general statement. The efficiency and amount of gasoline consumed in these two tests compare very favorably with the results obtained from centrifugal pumps of much larger capacity, and this fact tends to compensate in some measure for some of the disadvantages attendant upon the use of deep-well pumps.

The price of gasoline has been remarkably low (7½ cts. per gal.) in southern California, because of the fierce competition of oil producers and refiners in that region.* In other pumping localities 10 to 12 cts. a gal. is considered a low price for gasoline, and it is doubtful if the present low price will be long maintained in southern California.

*Report on Transportation of Petroleum, Bureau of Corporations, Department of Commerce and Labor, p. 426.

On account of the great and variable cost of wells, the total cost of plant bears no direct relation to the capacity of the pumping plant.

In many cases the charge for attendance and repairs on gasoline engines is merely nominal, but when there is a charge for attendance it is of considerable importance in comparison with the cost of gasoline. In nearly all the tests reported above the annual fixed charges for interest, depreciation and taxes, computed at 20% on the total first cost of the plant, far exceed the cost of gasoline, attendance, and repairs per year. This relation evidently depends upon the number of hours the pump runs per year. Since in many cases the pumps are used to supplement natural stream flow, the amount of use of the pumps fluctuates from year to year. Hence the interest on the pumping plant is in the nature of insurance on the crop, and it is scarcely fair to charge this item in its entirety as cost of pumping.

The cost has been reduced for purposes of comparison to cost per useful HP.-hr. under the items fixed charges, gasoline consumed, attendance and repairs, and total, and to cost per ft.-acre-ft. under the items gasoline consumed, and total. The latter are obtained from the corresponding items under the cost per useful water HP.-hr. by multiplying by 1⅛. The last columns of the table give the cost per acre-ft. of the water actually pumped under the headings for gasoline consumed and total. These are obtained from the preceding columns by multiplying in each case by the lift. These results are interesting as showing what it is actually costing irrigators in southern California to pump water.

ELECTRICALLY-DRIVEN PUMPS.—Tests numbered 12 to 24 are for electrically-operated pumps. Nos. 12 to 18 are centrifugal pumps arranged in order of useful water horse-power output, No. 19 is a screw pump, Nos. 20 and 21 are deep-well pumps, No. 22 is a triplex pump, and Nos. 23 and 24 are two tests on the same rotary pump. The electrically-operated pumps tested had approximately the same range in size as the pumps run by gasoline engines. The results are summarized in Table III.

As a rule, the plant efficiency for the electrical pump is definitely higher than for a corresponding plant operated by gasoline. This is probably largely due to the fact that proportionally less energy is absorbed in the motor than in a gasoline engine. There is less variation in efficiency due to size of plant for an electrically operated plant than for a gasoline plant. In Test No. 15 the efficiency was abnormally low.

As compared with centrifugal pumps, test No. 19 shows the screw pump to be less efficient; tests 20 and 21 show the deep-well pumps to have about an equal efficiency; tests 22, 23, and 24 show the triplex and rotary pumps to have somewhat higher efficiencies, but no very conclusive statements can be based on so few tests. The table shows that under the best conditions the smallest plants require about 1.6 KW. per useful water HP. and the largest about 1.4 KW.

STEAM-DRIVEN PLANTS.—Tests numbered 25 to 38 are of steam-driven pumping plants. Nos. 25 to 32 have centrifugal pumps, Nos. 33 and 34 are plunger pumps, and Nos. 36, 37 and 38 are air-lift pumping plants. Test No. 30 is based on Nos. 28 and 29, running simultaneously, and similarly No. 35 consists of Nos. 33 and 34 running together. All these plants burn crude oil as fuel. The largest ones are very much larger than any of the gasoline or electric plants tested and hence not strictly comparable with them. A summary of these tests follows:

For the plants using centrifugal pumps the plant efficiency does not seem to differ definitely from the efficiency for gasoline or electric plants. The plant efficiency of the plunger pumps is much higher than for any other type, while for the air-lift plants it is very much lower.

The amount of crude oil consumed varies from over 0.8 gallon per indicated horse-power hour for the smallest plant to a little over 0.2 gallon for the largest plants. For those using centrifugal pumps the amount of crude oil used per useful water horse-power hour varies from 2.5 gallons for the smallest plant to about 0.5 gallon for the most economical plants. A comparison with gasoline engines of corresponding size shows that four times as much crude oil is required under a steam boiler as is needed of gasoline in an internal-combustion engine. When run intermittently considerable fuel is required up steam preparatory to starting the plant probable that in such cases the actual per the plants required more fuel in proportion done than is shown in the tests.

Table V. gives a general summary of obtained with centrifugal pumps using ga electricity and steam (oil fuel) as the motive power prevailing in 1905 in the given locality.

Tests 2 and 12 afford a direct comparison of gasoline and electricity. The pump and piping same in the two tests, but the speed of the slightly higher when run by the electric motor, in an increased discharge from the pump. This be possible source of discrepancy in the result. The figures show for this plant the cost of gasoline 1 acre-foot of water 1 ft. high to be 3.7 cts., the cost of electricity to be 6.9 cts.; while the total for the gasoline plant is 6.9 cts. and for the electric plant 8.8 cts. per ft.-acre-ft.

Tests 16 and 26 afford a direct comparison of the use of electricity and steam. The two tests were made in succession on the same plant under identical conditions. The results show the cost of electricity per ft.-acre-ft. of water pumped to be 5.2 cts. and the cost of crude oil for producing steam to be 3.6 cts.

Tests 23 and 24 were carried out on the same plant. In No. 23 the plant was working under favorable conditions. In No. 24 the pump was sucking air on account of a deficient supply of water. The results show that in this case having the pump too large for the water supply increases by about 10% the charge for electricity per ft.-acre-ft. of water lifted.

STEAM MOTOR CARS ON THE INTERCOLONIAL RY., CANADA.

The Intercolonial Ry., of Canada, is one of the numerous railways now experimenting with steam motor cars, and it has cars of two different types in service. In both types a steam truck forms the motive power development. One of these is on the Ganz system, developed in Europe; in this system a high-pressure steam generator is used, and gearing is interposed between the engine shaft and the driving axle, as in the Wagenhals car, illustrated in our issue of April 25, 1907. The others are on the more common system in which the cylinders drive one axle directly and the wheels are connected by coupling rods.

GANZ STEAM CAR.—The car on the Ganz system is interesting on account of its special mechanical feaures and also from the fact of its being of a type which has been used quite extensively in Europe and is now being manufactured in this country. About 200 of these cars are now in use in Europe, and two cars for the Florida East Coast Ry. and the Intercolonial Ry. were imported from the works of Ganz & Co., Budapest, Hungary. The system is being introduced in this country by the Railway Auto Car Co., 114 Liberty St., New York, N. Y., which has shops at Peabody, Mass. This company has already supplied cars rated at 120-HP. each to the Erie Ry., the Florida East Coast Ry., the Intercolonial Ry., the Chicago, Rock Island & Pacific Ry., and the Delaware, Lackawanna & Western Ry. The first of these has been in operation on the Attica Division, near Rochester, N. Y. The second is described below. The third was a 43-ft. car with a single axle at each end. The fourth was built at the car company's shops and is of steel construction throughout, with interior finish of oak. It is 56 ft. long over the end sills, and

TABLE III.—SUMMARY OF COMPLETE TESTS ON ELECTRICALLY-DRIVEN PUMPING PLANTS.

No. of test.	Discharge. Per second. cu. ft.	Discharge. Per minute. galls.	Lift. feet.	Useful water horsepower.	Electrical horsepower.	Plant efficiency. perct.	Duration of test. h.	Duration of test. m.	Kilowatts.	Kilowatts per useful horsepower.	Number of hours plant runs per y'r.	Total kilowatt hours per year.	Cost of electricity per kilowatt h'r.	Total cost of plant.	Fixed ch'g's per yr at 15% on total cost of plant.	Cost of electricity per year.	Cost of attendance and repairs per year.	Total cost per year.	Cost per useful water horsepower hour. Fixed charges.	Cost per useful water horsepower hour. Electricity.	Cost per useful water horsepower hour. Attendance and repairs.	Cost per useful water horsepower hour. Total.	Cost per foot-acre-foot. Electricity.	Cost per foot-acre-foot. Total.	Cost per acre-foot of water pumped. Electricity.	Cost per acre-foot of water pumped. Total.
12	0.714	320	62.0	5.01	14.5	35	2	0	10.8	2.16	2,600	28,100	$0.02½	$1,150	$173	$657	0	$830	$0.013	$0.050	$0.00	$0.064	$0.069	$0.088	$4.28	$5.46
13	2.21	992	22 5	5.62	12.6	45	1	30	9.40	1.67	4,320	40,600	.02	2,500	375	810	$350	1,535	.015	.033	.015	.063	.045	.087	1.01	1.96
14	1.26	566	60.3	8.57	22.0	39	2	30	16.48	1.91	1,440	23,600	.02½	1,600	240	590	223	1,053	.019	.048	.018	.085	.066	.117	3.98	7.06
15	2.97	1,333	28.1	9.45	55.2	17	2	0	41.2	4.36	2,880	118,700	.018	3,000	450	2,130	500	3,080	.017	.078	.018	.113	.107	.155	3.01	4.36
16	1.38	620	94.3	14.7	31.9	46	3	0	23.8	1.62	.....	.....	.02½	.....	.....	.....	.....	.....	.....	.038	.....	.....	.052	.....	4.90	.....
17	1.10	494	132.4	15.3	31.6	48	4	0	23.6	1.54	558	13.200	.02½	3,400	510	330	132	972	.060	.039	.015	.114	.054	.157	6.61	19.20
18	1.82	817	188 9	39.0	71.2	55	3	0	53.1	1.36	3,000	160.000	.02½	6,000	900	4,000	1,200	6,100	.008	.034	.010	.052	.047	.071	8.88	13.90
19	.492	221	38.2	2.13	7.16	30	1	0	5.34	2.51	1,100	5.870	.02	1,500	225	117	0	342	.096	.050	.0	.146	.089	.201	2.61	7.68
20	.432	194	63.0	3.08	8.42	37	2	0	6.28	2.04	2,160	13.600	.02½	3.580	540	340	150	1,030	.081	.051	.023	.155	.070	.213	4.41	13.40
21	.750	337	63.0	5.36	13.1	41	2	15	9.76	1.82	2,160	21.100	.02½	4,950	740	530	150	1,420	.064	.046	.013	.123	.063	.169	3.97	10.60
22	.691	310	75.0	5.87	11.1	53	2	15	8.29	1.41	1,440	11,900	.018	3,000	450	214	100	764	.053	.025	.012	.090	.034	.124	2.25	8.30
23	.742	333	88.8	7.46	13.7	54	1	0	10.29	1.37	.....	.....	.02	.....	.....	.....	.....	.....	.....	.027	.....	.....	.037	.....	3.29	.....
24	.679	305	98.1	7.55	15.4	49	.	45	11.50	1.52	1,400	16,100	.02	2,000	300	322	0	622	.029	.030	.0	.059	.041	.081	4.02	7.95

seats 56 passengers (including 16 in the smoking room); it also has a 7-ft. baggage room. The weight is 35 tons in working order.

The car for the Intercolonial Ry. is shown in Fig. 1. At the front end is a boiler room 7 ft. long, which contains the steam generator, the operating levers, feed-water pumps, lubricators and small accessory apparatus. Next to this is a 7-ft. baggage room, then a smoking room for 8 persons, and the main compartment with seats for 32 passengers. At the rear end is a vestibuled platform. The car weighs 28 tons in working order and carries a supply of fuel and water sufficient for a run of 50 miles. It is fitted with air and hand brakes, steam heat, and an acetylene-gas lighting system. The frame and outside sheathing are of steel.

The boiler is of a high-pressure type, and consists of four vertical cylindrical shells forming two annular water chambers which are connected by a series of tubes; these are slightly inclined from the horizontal, and provide the greater part of the heating surface. The upper tubes, being in the steam space, serve to dry the steam and can superheat it by about 150° F. The volume of water is small, and a continuous feed is supplied by pumps, being automatically varied to correspond with the steam consumption. The working pressure is 260 to 300 lbs. The fuel (anthracite or bituminous coal) is fed from the top into the interior cylinder, and falls upon a grate beneath the boiler; the gases and products of combustion pass through the annular space between the two water spaces. The boiler is 3½ ft. diameter and 4 ft. high, and can develop 120 HP. The motor, Fig. 2, is a two-cylinder compound horizontal engine, with piston valves, and is suspended from the steel sills of the car. It drives the rear axle of the four-wheel truck through a single set of gearing with a ratio of 1 to 2.67. The tractive effort is about 4,000 lbs. The engine runs normally at about 800 r.p.m., but can be run at 1,100 r.p.m. All parts are enclosed, and the crank shaft, valve gears and driving gears run in an oil bath. The cylinders are lubricated by force-feed lubricators operated by an eccentric on the driving axle of the truck.

It is stated that before this car was accepted a number of trials were made by the Intercolonial Ry. The official test was from Moncton to Harcourt and return, a distance of 75 miles. The run from Moncton to Harcourt, 37½ miles, was made in 62 minutes, or at the rate of about 37 mi. per hr. The maximum speed was 43 mi. per hr. The total coal burned in the 75 miles was 925 lbs., which is equivalent to 12.3 lbs. per mile. The guarantee was for 16½ lbs. per mile. On a 1% grade one mile long from Moncton to Berry Mills a speed of 30 miles an hour was obtained. In another test over a distance of 26 miles, the steam car hauled a trail car weighing 24 tons and the average speed was 31 mi. per hr.

DIRECT-CONNECTED STEAM CARS.—These cars on the Intercolonial are of the same general design as many others in use in this country and abroad. The front end is carried by a four-wheeled steam truck on which the boiler is mounted, independent of the car body; outside cylinders drive the rear axle, while the wheels are connected by coupling rods. The design is somewhat similar to that of the Canadian Pacific Ry. steam car described in our issue of Aug. 2, 1906, but while the latter has a boiler of the marine return-tubular type (with corrugated firebox flue), the cars of the Intercolonial Ry. have vertical boilers resembling those used on the steam cars of the Great Western Ry. (of England), which were illustrated in our issue of July 28, 1904. The engine can develop about 200 HP. and is designed to give a speed of 25 mi. per hr. on a grade of 1%. It can also have a trail car when necessary. The car is of wooden construction and of ordinary design, except that an elliptical instead of monitor roof is used over the engine room. This part of the roof is of iron, and is removable so that the boiler may be lifted out.

FIG. 1. STEAM MOTOR CAR ON THE GANZ SYSTEM FOR THE INTERCOLONIAL RY.; CANADA.
Railway Auto-Car Co., New York, Builders.

The engine room is 13½ ft. long, and behind this is a baggage room 8½ ft. long; next to this is a smoking compartment 9 ft. long with seats for 12 persons, while the main compartment (30 ft. 3 ins. long) seats 40 persons. At the rear end are two toilet rooms. The vestibuled platform is extended to accommodate the apparatus necessary for operating the car when running with this end in front; this includes a lever connected to the throttle valve, a brake valve, and cords for the bell and whistle. This end of the car is carried by an ordinary four-wheeled passenger car truck. The cars are heated by steam and lighted by the vapor system of the Safety Car Heating & Lighting Co., using mantle lamps. The front end of the car has a cast-steel body bolster of diamond shape which surrounds the boiler, and is connected to a transverse bolster beneath the ash pan. This latter has a center plate engaging with a similar plate on a cast-steel truck bolster suspended from the truck frames by four hangers. These hangers have equalizing springs with caps seated in hemispherical sockets so as to allow for the motion of the car body in passing around curves. Vibration is checked by horizontal springs between the boiler and the bolster.

The steam truck has bar frames, connected by a cast-steel cross brace in front of the cylinders. The cylinders are outside and drive the rear wheels, as already noted. Coupling rods are used, and the slide valves are operated by Walschaert valve gears. Semi-elliptic springs are placed over the boxes, but are not equalized. The vertical boiler is 4 ft. 8 ins. diameter in the barrel and 6 ft. in the upper part, which forms a steam drum. There are 360 copper tubes 1½ ins. diameter, and as these extend 6 ins. above the water line (to the smokebox) they serve to dry or superheat the steam. The steam is taken from the top of the steam drum by a pipe leading to a T-head at the side. This carries the throttle valve and connections to the two steam pipes. The exhaust pipes parallel the steam pipes and connect with a T-head from which a pipe is led to the exhaust at the smokestack. Feed-water is supplied by injectors. The boiler rests on a cast-steel transverse frame which is seated on the truck frames and bolted to both the boiler and the frames. Two coal bunkers in the front corners of the boiler room carry together about a ton of coal; and 1,200 U. S. gals. of water are carried in tanks hung beneath the car. Three of these steam cars have been built at the railways shops at Moncton, N. B., to the designs of Mr. G. R. Joughins, Superintendent of Motive Power. Their general dimensions are as follows:

Length over end sills	66 ft. 0 ins.
Driving wheels	3 ft. 6 ins.
Truck wheels (trailing)	3 ft. 0 ins.
Wheelbase, steam truck	8 ft. 0 ins.
Distance c. to c. of trucks	49 ft. 0 ins.
Journals, driving axles	7 × 16 ins.
Boiler, diameter	4 ft. 8 ins.
Boiler pressure	180 lbs.
Firebox, diameter	3 ft. 10 ins.
Firebox, height	3 ft. 5 ins.
Tubes; No., 360; outside diameter	1½-in.
Tubes, height	4 ft. 10 ins.
Heating surface: tubes	685 sq. ft.
Firebox	44 sq. ft.
Total	729 sq. ft.
Grate area	11½ sq. ft.
Cylinders	12 × 16 ins.
Height, rail to top of smokestack	15 ft. 3⅜ ins.
Weight of steam truck (with boiler)	51,000 lbs.
Weight of car in working order	142,500 lbs.
Coal	2,240 lbs.
Water	1,200 gals.

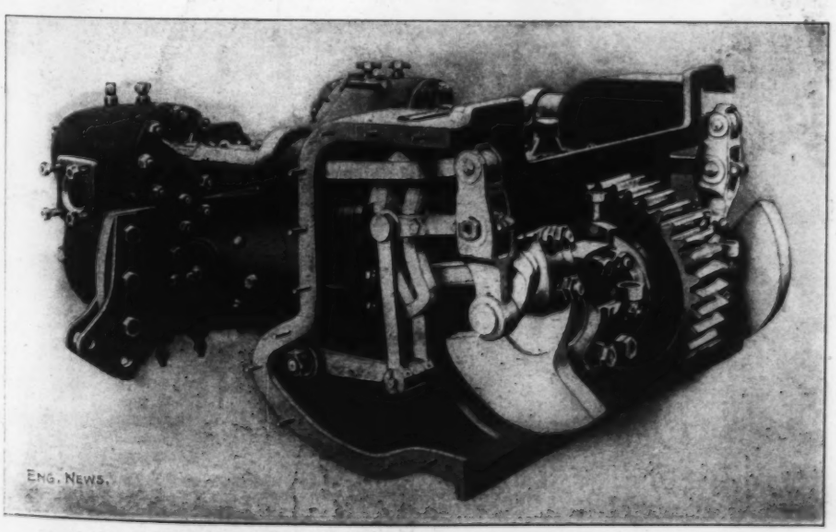


FIG. 2. ENGINE OF GANZ MOTOR CAR (WITH CASING REMOVED).

MOVING A HEAVY PIER SHED WITH FLOATING DERRICKS.

The interesting example of heavy moving work illustrated in the accompanying views was recently accomplished by Messrs. John Monks & Sons, Contracting Engineers of New York City. The section of pier shed moved is about 20 ft. long, 45 ft. high and 78 ft. wide and of an

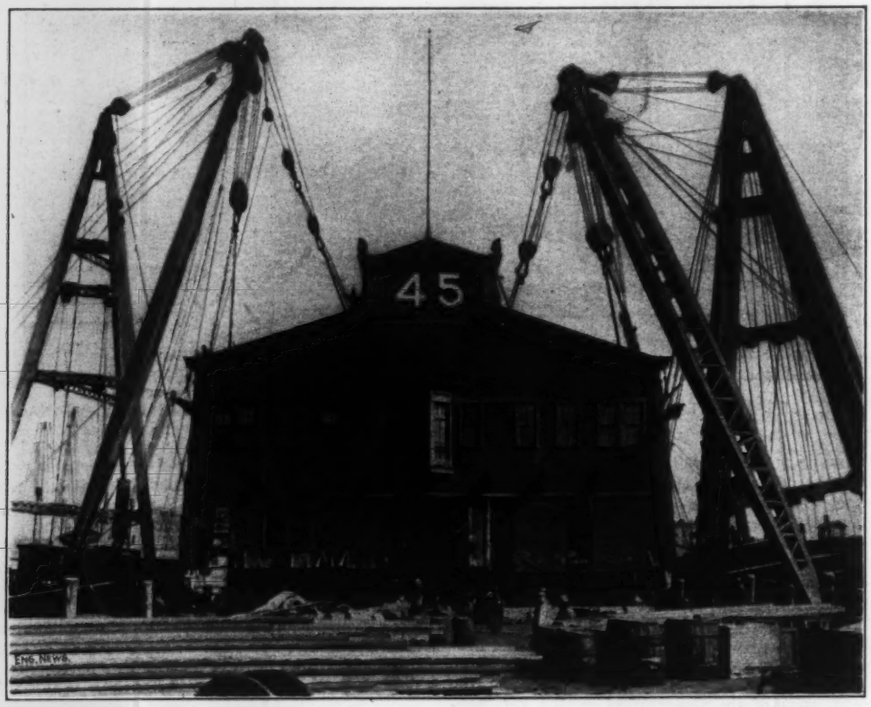


FIG. 1. MOVING A PIER SHED WITH FLOATING DERRICKS; VIEW LOOKING TOWARD SHORE.
John Monks & Sons, Contractors.

estimated weight of 60 tons. It is located about the middle of Pier 45 on the North River, New York City. Recently it was decided to enlarge the covered space on the pier, and estimates showed that it would be cheaper to cut the shed in two and move the outside end to the extreme outer end of the pier, building new work between the two parts than to tear down the gable end of the shed. Arrangements were made with the Merritt & Chapman Wrecking Co. for the use of two of its large floating derricks, and with these the detached portion of the shed was moved a distance of about 150 ft.

The shed was built about 30 years ago of wrought iron built-up column bents and roof trusses spaced about 20 ft. apart, with the columns fastened to base blocks by bolts and filled in between with a wall of fireproofing tile, which materially added to the weight of the structure. Owing to the lightness of the old construction, new roof trusses were built and additional knee-bracing was added to the columns. The shed was cut at a point about 20 ft. from the outer end, and in Fig. 2 it will be noted that a wooden temporary truss was substituted for the iron one originally at this point. The two derricks were floated to either side of the pier and chains were connected from each boom to the outer and inner edges of each side of the roof trusses, both at the hip and at the eaves. These chains were passed through the roof and fastened onto the bottom of the trusses. The bolts at the bottom of each column bent were then removed, the sheds lifted about 10 ft. from the wharf floor and the barges were moved by their own power to the new position of the section where bolts were already in place into which the columns were fastened. The whole work took only the better part of a day and the moving proper about 15 minutes. No part of the structure was seriously injured in moving.

We are indebted to Mr. J. W. Ripley, M. Am. Soc. C. E., Engineer in charge for the contractors, for the information and photographs herewith presented.

WORK ON THE MADEIRA & MAMORE RIVER RY. SURVEY IN BRAZIL.

In our issue of Oct. 24 we published a contribution relating to the survey of the Madeira & Mamore River R. R. in which certain charges were made concerning the accommodations and sanitary arrangements for the engineers.

We are now able to print portions of a letter just received from Mr. W. A. Welch, Principal Assistant Engineer of the expedition. The letter is dated at Santo Antonio, Nov. 10, and was a private letter written to an engineer friend in New York City, who is not connected with the railway company. We quote from it as follows:

Dear Sir: Your letter of Sept. 12th has just reached me and I will gladly give you the information you request.

Upon the arrival of the party at Santo Antonio, Mr. Miller, the Chief Engineer, at once started on a reconnaissance and left Mr. Sisson to erect the camp, on the island where there was good water and a good cleared camp site.

A party of the contractors' forces came up at the same time Mr. Miller's party did, to get some buildings up and get ready for the larger force which was to follow, and this party lived with the engineers until they were able to establish a camp of their own.

The sanitary arrangements of the camp established at Santo Antonio (on the island) were good, as evidenced by the fact that there was not a case of any sort of illness in that camp, other than malarial fever up to Oct. 12, when I moved the entire camp up the line.

As for being starved in that camp, I will say that we lived entirely upon the supplies which came up with the party in June, until Oct. 23, when the next ship arrived. And at no time was our camp mess, nor that of the other camp or the hospital, in any way below the average engineer camp mess in any way.

Beside our canned goods and the staples we brought down from New York, we have been able to purchase fruits, vegetables, eggs and fresh meat here, and all the camps have been supplied with these nearly every day. I have lived in camp most of the time for the past 20 years and have lived as well here as in any other camp.

There were filters supplied, at once, to all camps and at no time has there been any trouble with the water supply.

The Doctor, E. E. Shivers, had never been in the tropics before, but was raised and has always practiced in the swamps along the Mississippi River, as bad a malaria country as there is on earth. He thoroughly understands the treatment of every form of sickness we have had here, and he is a good surgeon.

Regarding the health conditions here I want to tell you plainly that in Santo Antonio and the vicinity there is a great deal of malaria. There are many mosquitoes and most of them are of the malarial type. I am the only one of the party who has not had an attack, and I did have a number of attacks while working in the Mississippi country. The fever yields readily to treatment and we have had no deaths or serious illness among the boys.

We now have another Doctor, H. P. Belt, who has had ten years' experience in Mexico, Central America, Cuba, the Philippines and South America. His wife, who is the best trained nurse I ever saw, is with him; and our hospital arrangements are all that can be asked.

We have moved our camps up the line and are in a fine, high, healthier country, no mosquitoes and good spring water. The contractors have established headquarters at Porto Velho, 7 kilometers below Santo Antonio, which is to be the terminus. It is a fine, dry place and comparatively free from fever.

The country ahead, which the line will traverse, is all from 100 to 150 ft. above the river and full of good springs and very few swamps and lakes in it, and I am sure the health of all the parties on the line will be as good as or better than on any tropical work I know of.

While I do not like being away from my family I am satisfied that I am in a very good place for the next few years. The work is not difficult, is like work on the Western plains, except for the dense forests.

Yours truly, W. A. Welch.

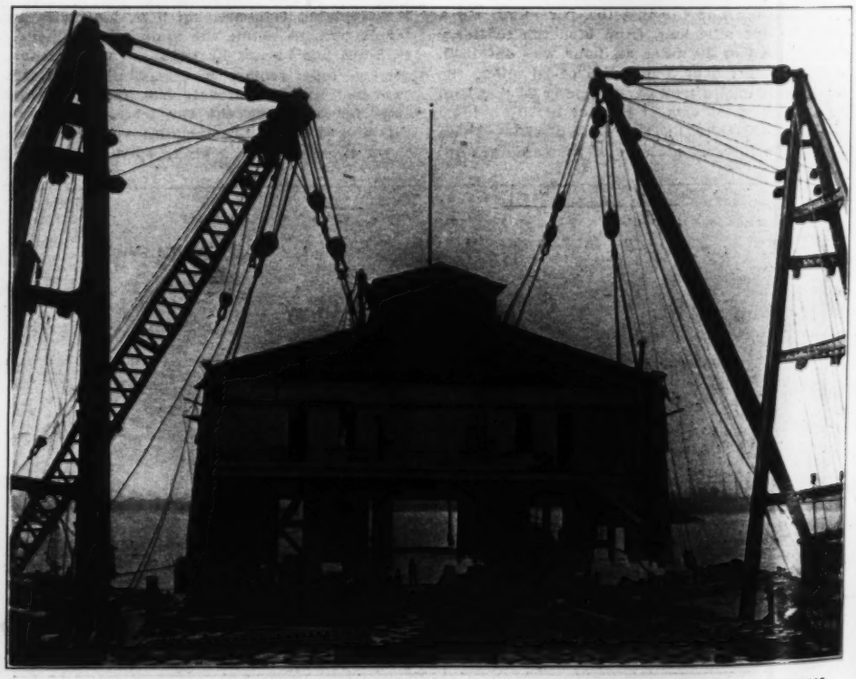


FIG. 2. VIEW LOOKING TOWARD RIVER, SHOWING PIER SHED SUSPENDED BY DERRICKS.

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The added safety afforded by two water supply mains is universally recognized, but the number of such mains which may be found lying side by side is evidence that there is but little recognition of the fact that to secure the maximum of safety duplicate mains should be so separated that a break in one will not mean the almost certain crippling of the other. We have referred to this matter before, but now, unfortunately, we can enforce our warning by a concrete example. The city of St. John, N. B., early this month, suffered a brief water famine (which of course might have been accompanied by a conflagration) through the breaking of a 24-in. and a 26-in. water main at a point where they had been laid close together. Of course we do not go so far as to say that duplicate water supply mains should never be laid side by side, for there are often great advantages in doing this, particularly when an existing right-of-way is sufficient for another main and a second right-of-way can be obtained only with considerable difficulty, delay and expense. But frequently a second main might be provided at a safe distance from the first with little additional trouble and expense, if only foresight were used in the original layout of works; or, this not having been done, if the location of the second main were given careful study. In the case of existing side-by-side mains the careful water-works official will take every reasonable precaution against breaks and their consequences, including the patrol and inspection of pipe lines, ready telephonic communication between patrolmen and headquarters, and, *never to be omitted*, repair material quickly available for use on any part of the lines.

The wreck of the seven-masted schooner "Thomas W. Lawson" brings to an unfortunate end the most interesting experiment in ocean transportation by sail-power that has been undertaken for many years. It has long been believed that the sailing vessel is doomed to extinction as a competitor for ocean freight transportation. In fact, it has already been beaten by the steam vessel in almost every trade, except a few very long voyages, where the coal consumption becomes so great as to seriously cut down the steam vessel's carrying capacity, and in the coasting trade between ports too small to support regular steamer lines or to attract tramp vessels.

It is in this latter trade on the Atlantic coast that the schooner has been developed from a small fisherman's craft to a vessel of large commercial importance. Several six-masted schooners have been built and are claimed to be commercially successful. The "Lawson" represented an attempt to carry the same idea still further, and a vessel was produced so large that it had to enter into direct competition with steam vessels to secure business.

While direct information is lacking, it is generally understood that the "Lawson" has not been profitable to her owners. Perhaps the attempt to restore the sailing vessel is doomed to failure, anyway. It seems to us, however, that the "Lawson's" record might have been different had she been equipped with auxiliary power. In fact, in discussing the design of the vessel at the time she was built, we expressed surprise that this had not been done.*

In the five years since the "Lawson" was built much progress has been made in the application of the internal combustion engine to marine use. It would to-day be possible, we judge, to equip a vessel like the "Lawson" with an oil engine of, say, 250 to 400 HP., sufficient to propel her at proper speed in harbors and other contracted waterways, where the manoeuvring of a large sailing vessel is difficult and dangerous. Such an equipment would save much expense in tug fees, much time in entering and leaving ports, and would be a great safeguard in the handling of the vessel in storms. The fuel consumption of such a power equipment, used for such purposes only, would be a very small item of expense, and the cost of attendance and repairs would also be small.

If the "Lawson" has been unsuccessful, therefore, it merely shows that sails alone cannot compete with steam, notwithstanding the advantage of the schooner rig over square sails. It still remains possible that the sailing vessel with an auxiliary internal combustion engine can beat the steamship; if not now, then in the future, when the inevitable advance occurs in the cost of coal.

If another object-lesson was needed to emphasize our comment last week on the need of State or Federal action to safeguard the lives of coal miners, it has been furnished by the third great coal-mine explosion occurring within two weeks. In this latest great tragedy, occuring in an Alabama mine, some fifty men appear to have lost their lives. From such information as the press dispatches give, there seems small room for doubt that it is the old story of a dust explosion. One wonders how many coal-mine owners in the United States understand the fact that the coal dust lying thickly along the passages of so many mines contains almost as great a potentiality of destruction as so much gunpowder.

It is stated that the United States Geological Survey contemplates a series of large-scale experiments on mine-gas and mine-dust explosions. Such experiments may have some value in attracting the attention of mine owners and mine managers to the need of greater care in guarding against mine disasters; but the facts regarding mine explosions were most thoroughly investigated more than twenty years ago. In the fall of 1886 there was published in Engineering News a series of papers giving the results of the investigation of a British commission appointed to investigate accidents in mines. Unless we are greatly mistaken, a large proportion of the casualties which disgrace the record of the American mineral industry are due to failure to observe precautions which were recommended by high authority over a score of years ago.

Submarine highway tunnels of exceptionally large cross-section are a notable feature in the means of communication between the districts lying north and south of the River Thames at London, England. There are two of these tunnels. The first is the Blackwall tunnel, 24 ft. 3 ins. inside diameter, completed about ten years ago; the second is the Rotherhithe tunnel, 27 ft. inside diameter, which is now approaching completion. The Blackwall tunnel* is 6,200 ft. long, of which 4,465 ft. are tunnel proper (1,200 ft. under the river), 1,382 ft. in "cut-and-cover," and 1,735 ft. in open cut approach. It has an outside diameter of 27 ft., and has a 16-ft. roadway with two sidewalks 3 ft. 1½ ins. wide; owing to the curve of the tunnel walls these narrow walks are extremely inconvenient. The approach grades are 1 in 34 and 1 in 36 (2.94% and 2.77%). The contract was let in 1891, and the tunnel was opened in May, 1897.

The new Rotherhithe tunnel is farther up the river than the other, and only a short distance from Brunel's first Thames tunnel (1842), which is now used for railway purposes. It connects the districts of Rotherhithe and Ratcliff, and crosses the river in a diagonal direction in order to most conveniently connect with the main streets and street railway lines, although no railway tracks will be laid through it. The tunnel has a cast-iron lining, and is being built by the shield system, under compressed air, although only a low pressure is required. A description of this work is given elsewhere, and was written for us by Mr. E. H. Tabor, M. Inst. C. E., Resident Engineer in charge for the London County Council. The work was commenced in April, 1904, and the headings of the pilot tunnel met in October, 1906. This tunnel is expected to be ready for traffic early in 1909.

The Rotherhithe tunnel presents two features of special interest in the construction work. These are the use of a pilot tunnel driven ahead of the main tunnel, and the use of an excavating machine for the pilot heading. The pilot or so-called "small" tunnel is itself 12 ft. 6 ins. diameter, which can only be considered small in comparison with the 30 ft. outside diameter of the main tunnel. The excavating machine is a revolving wheel carried at the head of the shield, and fitted with cutting knives and buckets. This revolves across the face of the heading, the excavated material being delivered by the buckets to a conveyor which extends back into the tunnel and discharges into the narrow gage cars. The wheel makes about 12 revolutions per minute, the knives cutting out concentric grooves and a central core. This machine is the invention of Mr. Price, of Price & Reeves, the contractors for the tunnel, and about a dozen of these machines were employed during 1904-1906 in boring the tunnels of the Great Northern, Piccadilly & Brompton Ry., which is one of the latest of the London electric rapid-transit "tube" railways. In the "tubes" of the Central London Ry., completed a few years ago, an excavating machine of a different type was used. It was on the principle of the ladder dredge, the ladder or boom being horizontal and fitted with an endless chain of buckets which discharged their contents through a chute at the rear of the boom. This boom extended in the axis of the tunnel, and projected through the shield, being so pivoted at the rear end that its head could travel over almost the entire surface of the heading. When it had excavated to a depth of 18 or 24 ins., the shield was forced forward, the cutting edge trimming off the unexcavated part inside its circumference. The saving in cost and time as compared with hand work was said to be very considerable. This machine was invented by Mr. Thomson, engineer for Walter Scott & Co., the contractors, and it was described and illustrated in Engineering News of May 19, 1898.

Comparatively little has been done in the application of excavating machinery for tunneling in soft material, especially for submarine work. In land work some use has been made of steam shovels modified in design to enable them to work in the restricted space available. Besides the

*Eng. News, Nov. 6, 1902.

*Engineering News: 1892, I. 615; 1894, II. 249, 311 1895, II. 115.

Rotherhithe tunnel, some other submarine tunnels also present interesting methods of construction. In the Hudson River tunnels, certain portions have been built without any actual excavation. The closed shield has been forced bodily through the soft silt, compressing and driving back the surrounding material. For the new Detroit River tunnel, and for tunnels carrying the Metropolitan Ry. of Paris (France) under the River Seine, the methods include the construction of tube or tunnel sections on shore; these being then floated out and sunk in position in a dredged trench. These methods, of course, are applicable only in very soft material for the former and with a very shallow depth of cover for the latter. They illustrate, however, the special methods which may be devised to meet special conditions.

We are accustomed to receiving all sorts of requests, for information, aid, counsel and assistance and some of these requests are responded to, so far as human fallibility and the limitations of a 24-hour day permit. It not infrequently happens, however, that we have to turn the seeker for information away unsatisfied, and one such is the writer of the letter which we print verbatim as follows:

Dear Sir:

Please send me the full list of the names & addresses of the responsible firms who construct the trolley & steam roads, dams, ditches, sewerage, etc., in the U. S., if possible. Can you tell me what pay do each firm give? I enclose you a stamp for reply & the full list.

Yours truly,

———— Springs, Conn., R. F. D. No. 1.

Our correspondent can have his stamp.

THE DESIGN FOR THE HUDSON MEMORIAL BRIDGE; NEW YORK CITY.

We illustrated in our issue of Nov. 21, the design prepared by the Department of Bridges of New York City for the Hudson Memorial Bridge over Spuyten Duyvil Creek at the upper end of Manhattan Island.

As our readers will recall, the design involves a reinforced concrete arch with the enormous clear span of 703 ft. According to the designers' figures, the concrete in this arch (which is 15 ft. thick at the crown and 70 ft. wide), will be subjected to a finit stress of 750 lbs. per sq. in.

It is very seldom that this journal takes the responsibility of criticising the design of an important engineering work; but we find ourselves compelled, after careful study, to do so in this case. We do not say that the great structure could not be built if unlimited expenditure of time and money is permissible; or that if built it might not stand up. What we do say is that the accumulated experience and knowledge of the engineering profession is not now sufficient to build a concrete arch of such enormous span with the assurance of safety that the public properly demands. In other words, the construction of this huge arch involves serious risk; and we can find no adequate reason why the City of New York should run such a risk.

It is not alone the mere money risk that we consider, though that is serious enough. The total cost of the great structure is estimated at nearly four millions, and the unprecedented difficulties to be met may make the cost far in excess of this sum. There is to be considered also the risk to life involved in a great structure whose margin of security is doubtful. There is further the risk of damage to the prestige of the engineering profession if this vast task should be undertaken and a failure should be made. This huge span has been adopted because the bridge is to be a monument; but it would be a poor memorial, indeed, of the man whose splendid achievements it is to celebrate, were the structure to be found impossible when partially built, or worse still if it were to fail or even show evidences of weakness or insecurity at any point after completion.

To build a concrete arch of 703 ft. span is not a mere step forward but a flying leap, and there is too much reason to fear it may be a leap in the dark. Not only is there no precedent whatever for the construction of a stone or concrete arch 700 ft. in span, but the largest concrete arch ever built has *less than one-third* this span.

If this small arch is considered a precedent for the huge structure, then let it be recorded that experience in constructing the largest spans thus far attempted in stone or concrete arches shows that difficulties are encountered far more serious than those met in structures of moderate size.

The superficial observer may argue that the task of erecting the 703 ft. arch is identical in kind with the task of erecting a similar structure only 200 ft. in span; that the differences are only those of degree; that the actions and exigencies in the one case are the same as in the other, and are therefore known; and that the mere exercise of proper engineering knowledge and ordinary skill is sufficient to allow for the changed degree of the various phenomena and troubles concerned.

This, however, is a fallacious argument. Limitations of size in actual experience prove to be very real. Practice demonstrates conclusively that arts and industries are generally advanced only by slow progression, and that danger is present in any sudden leap forward.

The recent accident to the Quebec bridge is a startling illustration. In that case the conclusions of sound and conservative designers, based on practice with structures of ordinary size, proved fatally erroneous when applied to a structure of another order of magnitude. In the present case, the fact that a concrete arch ring of 200-ft. span can be built in satisfactory manner without great risk or excessive difficulty is but slender support for the assertion that a 700-ft. span is feasible.

The most serious risks involved, it is to be noted, do not lie in the completed structure. We find little to criticize in the manner in which the designers appear to have carried out their plans and computations.

The calculations by which the great 703-ft. concrete arch was proportioned were painstaking and accurate. They appear to demonstrate satisfactorily that, if once the structure shown by the drawings could be built, and put in place, so that its parts would all act together in the manner assumed by the designer, the arch would then be capable of carrying its own weight and the superimposed loads with a fair margin of safety. It is true that an unusually high value has been chosen by the designers for the working-stress in the concrete; 750 lbs. per sq. in. is a high stress for concrete in such tremendous masses as are here involved, where the distribution of stress over a huge cross-section is a matter of which we actually know little. But with great care, rigid selection of materials and close supervision, a sufficient factor of safety to render this stress safe may be realized.

But the question that must be solved before the design can be by any means approved is, how can this huge mass be put in place over the deep valley and brought under stress in the way the designer has assumed? The theory and the calculations assume that the entire mass of concrete and the 8,500 tons of imbedded steel are simultaneously without stress (except for the stress in the steel due to its own weight), that they continue so until the centering which supports it during erection is struck, and that they assume stress in strictly uniform proportion as load is applied to the arch. The erection cannot be considered successful unless these conditions are at least approximately realized. Arrayed against the success of the endeavor to attain this end are the three great factors of (1) mobility of the centering, its settlement and elastic motion under load and temperature changes; (2) mobility of the steel reinforcement framework subject to similar influences; and (3) mobility of the growing mass of concrete, due to shrinkage in setting and expansion or contraction with temperature changes. The same problem, of course, is encountered in the erection of all concrete arches, but in short spans its difficulties are relatively small. As the spans grow larger, however, they increase in importance, and in the largest arches thus far built they have made the problem a very difficult one. With the length of span suddenly multiplied by three, the problem is certain to prove momentous.

For a very small arch the centering may be assumed to be perfectly rigid; its deflection and distortion have no measurable effect on the arch ring as it is laid up. In large arches, however, the behavior of the centering demands very careful attention. If the attempt were made to lay up a large arch progressively from one or both ends, as may be done with perfect safety in a small arch, the advancing wave of distortion of the centering would distort the growing arch, injure its integrity and, by giving the finished arch a shape other than that intended, vitiate the calculations on which the design was based. For this reason, large arches have always been thoroughly studied before construction to determine how the building-up of the ring may be distributed in order to minimize the effect of this distortion and eliminate its deleterious effects. Such study, which is of necessity largely empirical and guided by the experience gained in building other arches of nearly the same magnitude, must become highly speculative in the case of a structure very much larger than all previous ones.

The same observation applies in identical manner to the difficulties produced by the expansion and contraction of the concrete during the erection and the action of the steel in relation to the concrete, with the important exception, however, that the steel reinforcement proposed for the Hudson Bridge, being itself built as a self-supporting arch, introduces a complication not present in the erection of any of the large concrete arches hitherto built.

We have confined ourselves in the preceding solely to the difficulties in placing the arch ring so that stresses shall come into it in the manner assumed by the designer. That this must be actually effected, if the safety of the completed structure is to be a matter of knowledge and not of guesswork, every engineer will admit.

But let us look now at the stupendous task involved in placing the centering for the support of the arch. As shown in our issue of Nov. 21, the arch is to span Spuyten Duyvil Creek, a tidal stream with 24 ft. of water covering some 40 ft. of soft mud, underlaid by nearly an equal depth of sand. The total depth to solid rock varies from 70 to 140 ft. As the crown of the arch is 180 ft. above the water, a centering to support it, if founded on solid rock would have to be nearly 320 ft. high, or about the altitude of New York City's tallest office buildings. If we assume that this centering is to carry the weight of the arch ring alone, the total load upon it will be about 100,000 tons.

This vast weight must be carried on a temporary centering 700 ft. long by 70 ft. wide; a load of 2 tons per square foot of floor area. The necessary openings in the centering, for the railway tracks on the north bank and a mid-channel clearway for navigation, would still further complicate its construction.

We risk nothing in saying that in all the history of the human race, no structure has ever yet been erected to carry such a stupendous load at such a towering height.

The only possible alternative that we can see to the erection of such a centering would be to erect first a comparatively light steel or reinforced concrete arch, on centering which, though of equal height to that just described, would have comparatively moderate loads, and then proceed to build up the complete arch with the first arch as a support. Such a plan of erection would be wholly without precedent, would involve grave uncertainties as to the distribution of stresses in the final structure and ought by no means to be undertaken without the most thorough examination and expert criticism.

There are, indeed, cases in engineering work when risk is entirely justifiable. In pioneer work for example, it is often better to build a bridge which is close to the limits of safety, if available funds and materials make it necessary, rather than let people run the greater risk of fording a stream.

No thought of any such consideration enters into the design of the Hudson Memorial bridge.

In fact, it is as a monument rather than a bridge that the structure is now projected. There is no traffic now across the valley at the bridge site, and the traffic which in future years would undoubtedly seek a bridge at this point could be as well and more safely accommodated by a structure of conservative design and more moderate cost.

As already recorded in these columns the original design for a bridge at this point to be erected as a monument to the memory of Henry Hudson was for a bridge with a steel arch of 825 ft. span. The plans for this structure were rejected by the City Art Commission on the ground that a steel arch had not the certainty of long life that a structure designed to be a lasting monument should possess. It was then that the responsibility of designing a permanent structure fell to the Department of Bridges, and the design for the 703 ft. concrete arch was evolved.

It is not our purpose, here to say what design should be adopted for this Hudson Memorial bridge. Steel arches of great beauty have been built; we may mention notably the Alexander Bridge over the Seine in Paris, and the Washington Bridge, only a short distance from the Hudson Memorial site. We sympathize, however, with the desire to choose the most durable of materials for a monumental structure, and it seems to us possible to build a masonry bridge at this site which should be bold and architecturally pleasing without transcending the limits set by engineering knowledge and experience.

The design we have criticized adopts a maximum span; that is, a length of span which gives practically surface foundations. As already said, the result is a bridge in which the length of span is so great as to make its construction a venturesome experiment. The whole of the difficulty entailed by masonry arch construction has been thrown into the arch, and none into the foundations. Had the designers, by using river piers, put even half as severe a demand on the foundation-builder as upon the arch builder, they would have secured a compromise design much nearer the present-day limits of arch construction.

A second point of criticism is the selection of concrete in place of stone for the arch. Even the strongest advocates of concrete will admit the advantages of stone, not only structurally but from the viewpoint of beauty and monumental effect. The best building stones are far stronger than concrete. An arch ring of given size, especially where live-load moments are vanishingly small, as here, so that tensile resistance never comes into play, can therefore be made considerably thinner of stone than if made of concrete. The weight of the arch ring would therefore be reduced almost correspondingly, and, as this is one of the largest fractions of the total load, still further saving in the ring thickness could be effected. It is apparent that the falsework difficulties would be much reduced by the lighter weight of the ring. Still more important, in our opinion, is the elimination of the shrinkage troubles and attendant difficulties which must beset the construction of the concrete arch. Finally, the elimination of the imbedded steel, made possible by the higher strength of the stone, removes a further source of uncertainty, not to mention cost, in the construction of the arch ring.

On every count, it seems to us, the stone arch claims preference over the concrete arch for the bridge in question. Whether it was considered or why it was rejected, we are unable to say. Perhaps its greater cost defeated it. But the cost consideration was already thrown to the winds in the rejection of the steel arch; for the concrete design contains enough reinforcing steel alone to build the entire arch of steel.

LETTERS TO THE EDITOR.

Concerning Bidders for Navy Department Contracts.

Sir: The Bureau recently forwarded to certain manufacturers—100 in all—a circular letter explaining the recent improvement in the contract business of the Navy Department as regards: (a) waiving of bonds and contracts on proposals less than $500 in value; (b) unloading, at Government expense, deliveries at navy yards; (c) obviating delays in payment for deliveries made, and (d) abolishing 10% reservation from value of deliveries, etc., with a view to encourage competition, thus eliminating certain objectionable features of bidding.

This letter has been given widespread attention through certain mediums—trade journals, jobbers' associations, etc.—and the impression has been created and disseminated broadcast throughout the country that the Bureau intends to confine competition to manufacturers only, by refusing to consider bids from the wholesaler, jobber, retailer and middleman.

The Bureau has neither the desire nor the power to exclude any reputable dealer from bidding on naval supplies. All bids from such persons will be given the same consideration, and in each case award will be made to the lowest formal responsible bidder. By reason of the onerous requirements under the old form of contract, many responsible firms were unwilling to deal directly with the Bureau. By removing these onerous conditions it is hoped that such firms will bid directly for the Navy business, and, by thus widening competition, give to the Navy better prices and prompter deliveries.

Respectfully,

E. B. Rogers,
Paymaster-General, U. S. N.

Washington, D. C., December 14, 1907.

Why Do Some Structures Stand?

Sir: Your editorial in Engineering News of December 12 in which you say, "there is often as much to be learned from a structure which transgresses accepted rules of design and still stands up as from one which falls down," greatly interested at least one of your readers.

Some twelve or fifteen years ago the writer was asked to report on the strength of some roof trusses. The trusses were a curious combination of cast and wrought iron. They were built in the '50's, but beyond that little was known of their origin. With a liberal charity in the matter of unit stresses they could not be found to have a factor of safety much greater than two. The trusses were consistent in that they were of equal strength or weakness in all their parts. The conclusion of the report was, "the trusses are liable to fall down at any time." This report displeased the owners who were trying to sell their property and they dismissed it with the remark, "the roof has stood up for 35 years and we guess it is good for some years to come." And it did last for seven years more. One February there came an unusual fall of snow—a blizzard in fact, and the trusses collapsed. Here again was consistency. The roof for the entire area dropped as if it was one piece. It was in the night, so there was no loss of life, but the machinery underneath was damaged. But what held up that roof for 42 years?

The designer in structural steel is continually meeting similar problems. Two iron highway bridges with the joists laid transversely to the roadway and resting *on the lower chord bars* come to mind. These two bridges have stood up for nearly thirty years. Within five miles of these bridges is a railroad bridge built about the

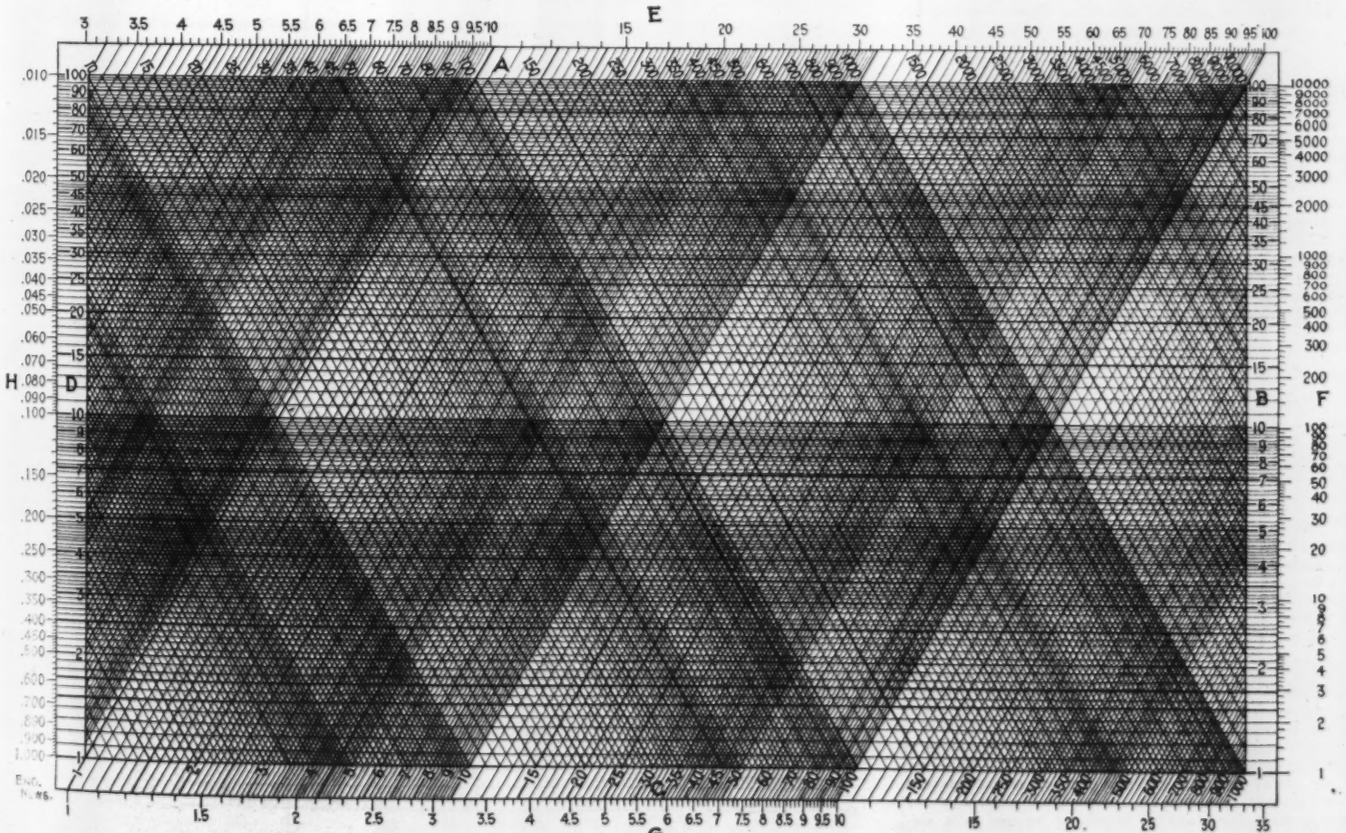

FIG. 1. THREE-SCALE LOGARITHMIC COMPUTING PAPER.

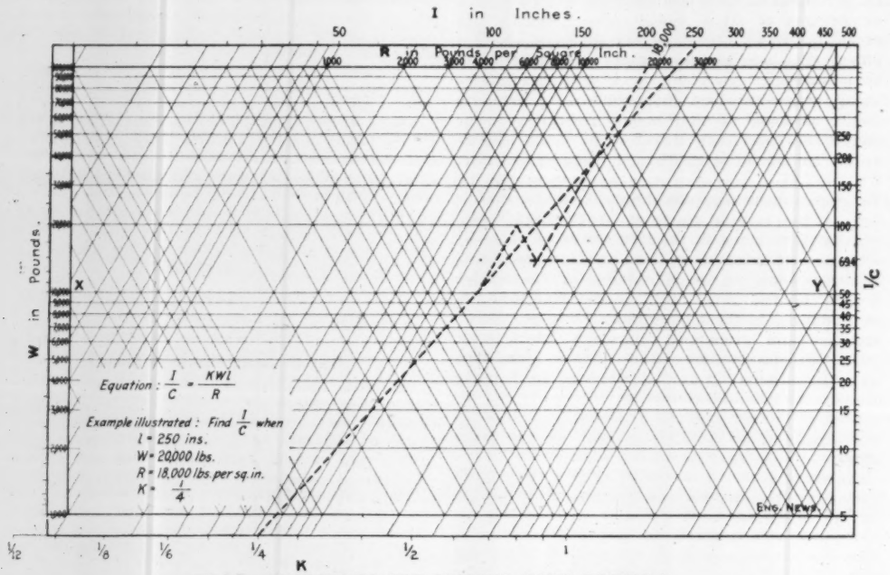

FIG. 2. PROCEDURE FOR SOLVING BEAM FORMULA.

same time in which 3-in. pins and less are used in the packing of 6-in. chord bars.

Some steel mill buildings are flagrant transgressions of standard specifications. Plate girders carrying traveling cranes are often deficient in lateral stiffness and in details.

In many cases the loads for which the structure is supposedly designed do not come upon it. This is probably the reason why the highway bridges or the crane girders mentioned above do not fail. In other cases the assumptions made are in error. How many steel mill buildings would be standing today if some of the methods of figuring wind stresses presented in Engineering News the past three or four years are correct?

There is still a large number of existing structures in which we ask almost hopelessly, "What keeps them up?"

Yours very truly,

R. F.

New York City, Dec. 13, 1907.

Three Scale Logarithmic Computing Paper For Solving Formulas.

Sir: The design of cross-section paper shown in the drawing herewith (Fig. 1) may prove of interest.

It will be noted that the lines run in three directions, meeting at angles of 60°, and that all three sets of lines are spaced logarithmically, starting from the lower left-hand corner, as origin, in each case. For convenience in referring, the horizontal lines will be called "a" lines, the oblique lines running from the lower left-hand corner to the upper right-hand corner will be called "b" lines, and those running from the upper left-hand corner to the lower right-hand corner will be called "c" lines. The inner scales on the top, right-hand side, bottom and left-hand side will be designated as A, B, C and D respectively.

This arrangement of lines and scales serves as a device for the addition and subtraction of logarithms, and consequently for multiplication and division. For instance, to multiply 20 by 6 (Fig. 1), find 20, say, on the D scale, and follow in "a" direction, i. e., along an "a" line, to the "b" line corresponding to 6 on the C scale. From this intersection follow in "c" direction to the result, 120, on either the A or the C scale. By a reversal of this process division can of course be performed. It will be seen at once that by combining two or more of these multiplications or divisions, we have a method for the graphical solution of various equations.

The auxiliary scales, E, F, G and H, Fig. 1, are added to aid in the solution of equations containing squares, square roots, reciprocals, etc. Scales E and G are twice scales A and C, and therefore transferring from A or C to E or G gives the square root, and transferring from E or G to A or C gives the square. Scale F is one-half scale B, and hence transferring from B to F gives the square, and from F to B gives the square root. Scale H is the same as scale D, except that it is reversed, i. e., plotted from the top downwards. Therefore transferring from C to H, or from H to C, gives the reciprocal of the original number.

The examples shown in Figs. 2, 4 and 5 will serve to illustrate how formulas of various types may be solved by use of this paper. These figures are not intended to be used as charts for the practical solution of the equations illustrated, but merely to indicate in a diagrammatic way the arrangements for their solution.

Fig. 2 shows the arrangement for the solution of the formula,

$$\frac{I}{c} = \frac{K W l}{R},$$

for the section modulus of a beam, in which K is a constant depending upon the form of beam, W is the weight on the beam in pounds, l is the length of the beam in inches, and R is the allowable maximum fiber-stress in pounds per square inch. The length l is

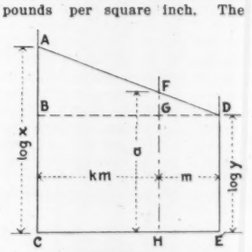

Fig. 3.

plotted along scale E, the coefficient K along scale G, the load W along scale D, the fiber-stress R along scale A, and the result $\frac{I}{c}$ along scale B. More or less juggling of the formulas is often necessary in order that the various scales may be used to the best advantage. In this particular case the factor 5 was introduced in plotting l, and the factor ½ in plotting R, thus making the result 2½ times as large as it would otherwise be. This is allowed for in plotting the result on scale B.

Let us take a numerical case in which $K = ¼$, $l = 250$, $W = 20{,}000$ and $R = 18{,}000$. First a straight edge is passed through the given values of l and K, and the intersection with X Y, the middle line of the set, is noted. This intersection continued in the "b" direction represents the product of l and K. The principle by which this multiplication is done will be understood from the following explanation.

Referring to the sketch, Fig. 3, let $A C$ and $D E$ be two parallel lines proportional to log x and log y respectively. The line $F H$ is drawn parallel to $A C$ and $D E$, at a distance m from $D E$ and $k m$ from $A C$. The line $A D$ is drawn, intersecting $F H$ at F.

Then

$$F H = D E + (A C - D E)\frac{m}{k m + m},$$

$$= D E + (A C - D E)\frac{1}{k+1};$$

or, letting $F H = a$,

$$a = \text{log. } y + \frac{\text{log. } x - \text{log. } y}{k+1},$$

$$= \frac{\text{log. } x + k \text{ log. } y}{k+1}.$$

Hence

$$\log^{-1} a = \sqrt[k+1]{x y^k} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

By taking k equal to the ratio of the powers desired, any combination of powers under the radical may be obtained. For instance, if we want $x^2 y^3$, let $k = \frac{3}{2}$.

Then

$$\log^{-1} a = \sqrt[\frac{5}{2}]{x y^{\frac{3}{2}}}$$

$$= \sqrt[5]{x^2 y^3}$$

In the present case, Fig. 2, we take $k m = m$, i. e., $k = 1$. Substituting in (1),

$$\log.^{-1} a = \sqrt{x y}.$$

The middle line, on which the product is read, is plotted to half as large a scale as the original scales E and G with which we started. This squares the result, thus removing the radical from the last-given expression.

Now, having found the product of K and l, follow in the "b" direction to the "a" line representing W. This gives $K l W$. Now follow in "c" direction to "b" line representing R, and then follow in "a" direction to the result $\frac{K l W}{R}$, or $\frac{I}{c}$, on scale B.

Fig. 4 shows the arrangement for the solution of the formula for the deflection of a helical spring of round wire. The equation is

$$F = \frac{8 P D^3}{E d^4}.$$

Where F is the deflection per coil in inches, P is the load in pounds, D is the mean diameter of the coil, d is the diameter of the wire, and E is the torsional modulus of elasticity. For convenience in plotting, the equation was put into the following form:

$$\frac{1}{F} = \frac{\frac{E}{d^4 D^3}}{P}.$$

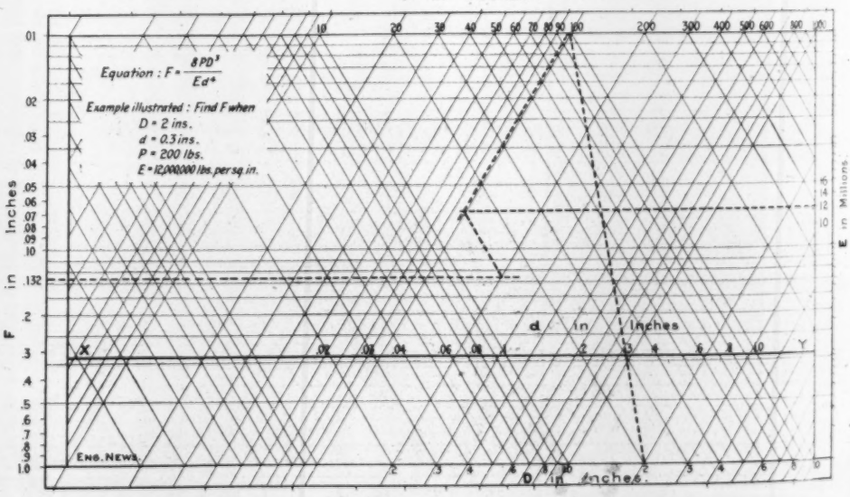

FIG. 4. PROCEDURE FOR SOLVING FORMULA FOR DEFLECTION OF HELICAL SPRING.

Referring again to Fig. 3, substitute in Eq. (1) the value $x = -\frac{3}{4}$, $x = d$ and $y = D$.

Then

$$\log^{-1} a = \sqrt[4]{x\, y^{-2}}$$
$$= x^{\frac{1}{4}} y^{-\frac{1}{2}} = d^{\frac{1}{4}} D^{-\frac{1}{2}}.$$

If we draw a horizontal line three-quarters of the distance from scale A to scale C, and plot d along this line, to along scale C, and read the product at scale A, the conditions implied in equation (3) will be satisfied.

The value of $\frac{E}{8}$, marked E, is plotted along scale B, P along scale A, and the result, F, along scale H. It will be noted that the result, according to the inverted form of the equation, would naturally be $\frac{1}{F}$, but the fact that we are using the reciprocal scale, H, inverts it, giving us F.

Let us take as a numerical case $P = 200$ lbs., $E = 12{,}000{,}000$ lbs. per sq. in., $D = 2$ ins., and $d = 0.3$ in. In solving, first pass a straight edge through the given values of D and d and note the intersection on scale A. This gives $d^{\frac{1}{4}} D^{-\frac{1}{2}}$ in one operation. From this intersection follow in "b" direction to the "a" line representing E. This gives $\frac{E}{8} d^{\frac{1}{4}} D^{-\frac{1}{2}}$. Now follow in "c" direction to the "b" line representing P and read the result F in the "a" direction on scale H.

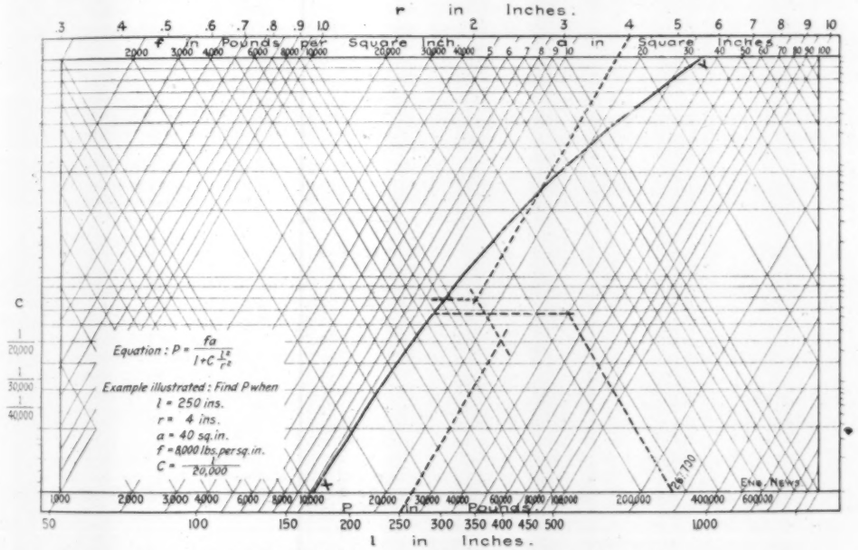

FIG. 5. PROCEDURE FOR SOLVING COLUMN FORMULA.

Fig. 5 shows the arrangement for the solution of Gordon's column formula,

$$P = \frac{f a}{1 + C\frac{l^2}{r^2}}$$

in which P is the load in pounds, f the allowable maximum fiber-stress in pounds per square inch, a the area of a cross-section of the beam in square inches, C a constant depending upon the form of column, l the length of the column in inches, and r the radius of gyration in inches.

It will be noted that this equation contains an addition constant. Of course non-factorable equations cannot be handled on this chart without the use of curves; but one or two simple and easily plotted curves will make solvable many formulas of this type.

In this case l is plotted along scale G, r along scale E, the reciprocal of C (marked C') is plotted along the reciprocal scale H, f along scale A, a along scale A, and the result, P, along scale C. The curve X Y is so drawn that transferring from an "a" line at its intersection with the curve to a "b" line increases the "a" scale quantity by 1.

Let us take as a numerical case: $l = 250$ ins., $r = 4$ ins., $C = \frac{1}{20{,}000}$, $f = 8{,}000$ lbs. per sq. in., and $a = 40$ sq. ins. Follow from given value of l in "b" direction to "a" line representing C'. Then follow in "c" direction to "b" line representing r, and follow in "a" direction to an intersection with the curve X Y. From this intersection follow in "b" direction to "c" line representing f and follow in "a" direction to "b" line representing a and read the result in "c" direction on scale C.

These few examples have, I think, shown the possibilities of this chart for use in the practical solution of various engineering equations. Its chief advantage over ordinary graphical methods of solving equations is its greater simplicity. For simple equations no curves whatever are necessary and even for more complex equations, involving addition or subtraction constants, trigonometric functions, etc., the necessary curves are simple and easily plotted. Even very complex non-factorable equations containing several independent variables may be solved by the use of families of curves. This chart is particularly well adapted to the solution of equations containing variables with fractional exponents. A straight line drawn at the proper angle will give any power that may be desired. Paper of this design will be found especially useful in laying out charts for finding the weights of rolled steel structures, for computing shop costs, and in solving many other similar problems.

It may be argued that this chart is merely the slide-rule transferred to paper, and that the result is merely an awkward substitute. That it is to some extent a substitute for the slide-rule is true, but it must be recognized, I think, that something is gained by the substitution. In the first place, in the solution of most equations there will be fewer operations in the use of this paper than with the slide-rule. Then, too, in certain cases time may be saved by the way the variables are plotted. Lengths, for instance, may be plotted in feet and inches, and thus the time of changing from a mixed number of feet and inches to inches saved; in fact, this might have been done to advantage in Figs. 2 and 5. Perhaps the greatest advantage, however, of this chart over the slide-rule is in the matter of locating the decimal point. There are very few users of the slide-rule who are not at times bothered as to the location of the point. In solving an equation by this chart there can be no such difficulty, as the complete result is read directly. There is one location on the scale for 100 and an entirely different one for 1,000.

This chart is not offered as a general substitute for the slide-rule, but merely suggested as a better means of solving certain stock equations.

Yours truly,
S. Jay Teller.

708 North 19th St., Philadelphia, Aug. 12, 1907.

Notes and Queries.

In the paper on "Peat Fuel," by Mr. F. J. Bulask, abstracted in the article on "The Organization of the American Peat Society," which appeared in our issue of Oct. 31, the author was quoted as stating that the analyses of fuel gas from six samples of Mexican peat showed an average of 24.45 cu. ft. per ton of dry fuel and a maximum figure of 35.33. These figures as quoted should apply to thousand cu. ft. instead of cu. ft. Expressed in the latter terms the values named should read 24,450 and 35,300 cu. ft., respectively.

AN OLD WOODEN BRIDGE across the Souhegan River, near Greenville, N. H., was destroyed by fire on Dec. 9th. The bridge was built in 1850 for what was then the Shirley & Peterboro R. R., a road afterwards under the control of the Boston & Maine R. R. It had a total length of 668 ft, in three spans and crossed a gorge about 100 ft. in depth.

A MINE EXPLOSION in mine No. 1 of the Yolande Coal & Coke Co., at Yolande, 35 miles south of Birmingham, Ala., on Dec. 16, killed at least 50 men and injured many others. There were 90 men in the mine at the time of the accident and up to eight hours afterward 30 bodies had been recovered and 25 men had been rescued alive. There has been as yet no satisfactory explanation of the cause of the explosion, but as the State Inspectors have recently declared the mine free from gas it is supposed that the accident was due to an explosion of coal dust. As the fans were not damaged it was possible to get them working soon after the explosion, and it is probable that their efforts in cleaning out the foul air saved the lives of many of the men who were not killed by the first shock.

Six men were killed in an explosion in the Dinas coal mine in Wales on Dec. 14. The disaster was caused by a premature discharge of a blast upon the surface of the mine, on account of which the top of the shaft was blown out and there was a great fall of rock into the mine.

THE SEVEN-MASTED SCHOONER "Thomas W. Lawson," the largest fore-and-aft vessel ever built, foundered in Broad Sound, Scilly Islands, just off the southwesterly tip of England, on Friday, Dec. 13. The Lawson was carrying oil from Philadelphia to London, and had had a difficult passage since sailing from port on Nov. 19. Reaching the Scilly Islands in heavy weather, Capt. Dow thought it best to cast anchor. The storm increased to a hurricane, and while life-boats were endeavoring to rescue the crew of 18, the schooner capsized. Only three of the men were saved. The Lawson was designed by B. B. Crowninshield of Boston, was 403 ft. in length, 50 ft. in beam and 34½ ft. in depth. All steering and handling was done by steam, and lighting by electricity. The schooner was built in 1902. It was expected to create a new development in merchant shipping, but no other seven-master has been built. Yet the vessel is said to have been highly profitable.

THE HYDRAULIC DREDGE "ILLINOIS," recently built for the Lincoln Park Commission, of Chicago, for the improvement work on the lake front, was sunk during a storm on Dec. 9. The dredge was being towed to its winter quarters and was off 40th St. when it was swamped. There were 28 men on board, but all were rescued by the tug.

PERSONAL.

Mr. G. S. McKinnon has been appointed Assistant Master Mechanic for the Canadian Northern Ry., with headquarters at Winnipeg, Man.

Mr. L. H. Taylor, late of the Truckee-Carson project of the U. S. Reclamation Service, has become Supervising Engineer with the California-Nevada Power Co.

Mr. Robert Hoffmann, M. Am. Soc. C. E., has been appointed City Engineer of Cleveland, Ohio, to succeed Mr. Wm. J. Carter, who has resigned to go into private practice.

Mr. Wayne A. Clark has been promoted from Assistant Engineer to Chief Engineer of the Duluth & Iron Range Ry., to succeed the late Robert Angst, whose death is noted below.

Mr. Walter P. Hall, of Fitchburg, Mass., has been appointed by Gov. Guild, of Massachusetts, as Chairman of the Massachusetts Railroad Commission, to succeed Mr. Jas. F. Jackson, who recently resigned.

Mr. D. C. Moon has been promoted from Assistant General Manager to General Manager of the Lake Shore & Michigan Southern Ry., to succeed the late E. A. Handy, whose death was announced in this column on Nov. 28.

Prof. J. P. Jackson, M. Am. Inst. E. E., who has been Professor of Electrical Engineering at the Pennsylvania State College, has recently been appointed to the position of Dean of the School of Engineering of that institution.

Mr. William J. Carter, M. Am. Soc. C. E., who has been City Engineer of Cleveland, Ohio, for the past seven years, has resigned to open an office in the Rockefeller Building, Cleveland, for the general practice of civil engineering.

Mr. Charles H. Kluegel, M. Am. Soc. C. E., has been appointed Territorial Engineer of Hawaii, with headquarters at Honolulu. Mr. Marston Campbell has been appointed Superintendent of Public Works of the same territory.

Capt. George M. Hoffman, Corps of Engineers, U. S. A., has been detailed as assistant to Maj. Jadwin, on the Chagres Division of the Panama Canal. Capt. Hoffman has recently been on duty at Vicksburg, Miss., and Galveston, Tex.

Mr. C. M. Hobbs, late General Manager of the Nevada-California Power Co., has resigned that position. Mr. David A. Chappell, who has recently been elected President of the company, will assume also the duties of General Manager.

Obituary.

E. B. Reynolds, one of the largest of the western railway contractors in the last quarter of the nineteenth century, died at his home in Wymore, Neb., on Dec. 7.

Thomas J. Hurley, M. Am. Inst. Min. Eng., died at his home in Brooklyn, N. Y., on Dec. 13, at the age of 60 years. He was connected with many mining and street

railway enterprises and was President of the Precious Metals Corporation.

Sir William Thomson, better known to the scientific world as Lord Kelvin, died at his home in London on Dec. 17, aged 83 years. The distinguished character of his service in the fields of applied and pure science placed him among the foremost figures of his century. A more detailed biography will appear in our next week's issue.

Marcellus Hopkins, President of the South Side Elevated R. R. of Chicago, died in Chicago on Dec. 7. Mr. Hopkins worked up through the Chicago & Northwestern R. R. into the street railways of Chicago, becoming General Manager of the South Side Elevated R. R. at its foundation, and was promoted from that position directly to the one he held when he died.

William Bliss, President of the Boston & Albany R. R. for the last 27 years, died at his home in Boston on Dec. 14. Mr. Bliss was born in Springfield, Mass., Dec. 11, 1834. He entered railway work in 1855 as assistant to the President of the Western R. R. of Mass. and became General Freight Agent of that road in 1866. In 1872 he was appointed General Manager of the Boston & Albany R. R. and was elected President in 1880.

Robert Angst, M. Am. Soc. C. E., Chief Engineer of the Duluth & Iron Range Ry., died at Duluth, Minn., Nov. 30, 1907, at the age of 60. He was born at Wyl, Switzerland, on June 2, 1847, and came to this country in 1869. He entered at once into railway service, and became Chief Engineer of the Duluth & Iron Range Ry. in 1887. He gave particular attention to the design of the large ore shipping docks or piers required by the ore railways at the ports on the upper lakes. He is survived by a wife and seven children.

Charles P. Matthews, Professor of Electrical Engineering at Purdue University, died at Phoenix, Ariz., on Nov. 23. Prof. Matthews was born in Fort Covington, N. Y., on Sept. 18, 1867. He received his elementary education in Vermont and entered Cornell University in 1888, graduating therefrom in 1892 with the degree of Mechanical Engineer. In 1901 he received the degree of Doctor of Philosophy from Cornell. After graduation he became instructor in physics and applied electricity at Cornell University and served in that capacity until 1896 when he became Associate Professor of Electrical Engineering at Purdue University. In 1905 he was appointed to the head of the School of Electrical Engineering at Purdue. Prof. Matthews' main professional work outside of his professional capacity was in connection with the National Electric Light Association, for which he directed all photometric investigations, preparing the voluminous report which they recently published. For these experiments he invented and patented an integrating photometer. He was the author of several professional papers in addition to being a collaborator with Professors Nichols and Schearer, of Cornell, and Esterline, of Purdue, in text-books in physics and electricity. He was a member of the American Institute of Electrical Engineers.

Thomas Fitch Rowland, one of the distinguished figures in American engineering, died at his home in New York City on Dec. 13, at the age of 76 years. Mr. Rowland started his engineering work as fireman and engine driver for the New York, New Haven & Hartford R. R., leaving this to become an engineer on a steamboat plying between Hartford and New York. In 1852 he entered the Allaire Iron Works in New York as draftsman, which position he resigned in 1853 to become General Superintendent of the Atlantic Dock Iron Co., of Brooklyn. In 1859 he established at Greenpoint, N. Y., an iron works of his own, which in 1887 he incorporated as the Continental Iron Works and of which he became President and General Manager. He was very prominently connected throughout the Civil War with the iron construction work of the United States, building for the Government gun carriages and ship fittings. His crowning work during the war was the construction in 1862 of the famous "Monitor," after the designs of John Ericson. Mr. Rowland was a member of many engineering societies, but was more prominently connected with the American Society of Civil Engineers, of which he was one of nine honorary members, and the American Society of Mechanical Engineers, of which he was a past vice-president and a life-member. He was also the donor to the American Society of Civil Engineers of an annual prize, known as the Thomas Fitch Rowland Prize, for papers describing in detail accomplished works of construction, their cost, and errors in design and execution. He is survived by a wife and three sons.

ENGINEERING SOCIETIES.

COMING MEETINGS.

AMERICAN ECONOMIC ASSOCIATION.
Dec. 28-31. Twentieth annual meeting at Madison, Wis. Secy., Winthrop M. Daniels, Princeton, N. J.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
Dec. 30-Jan. 4. Annual meeting at University of Chicago. Secy., L. O. Howard, Cosmos Club, Washington, D. C.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
Jan. 15. Annual meeting at New York City. Secy., Chas. Warren Hunt, 220 West 57th St., New York City.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.
Jan. 15-17. Annual meeting at Champaign, Ill. (University of Illinois). Secy., E. E. R. Tratman, 1636 Monadnock Block, Chicago.

INDIANA ENGINEERING SOCIETY.
Jan. 16-18. Annual meeting at Indianapolis. Secy., Charles C. Brown, 408 Commercial Club Building, Indianapolis.

NATIONAL ASSOCIATION OF CEMENT USERS.
Jan. 20-25. Fourth annual convention at Buffalo. President, Richard L. Humphrey, 1001 Harrison Bldg., Philadelphia, Pa. Convention Manager, Dal H. Lewis, 760 Main St., Buffalo.

WOOD PRESERVERS' ASSOCIATION.
Jan. 21. Fourth annual meeting at Kansas City. Secy., C. W. Berry, Laramie, Wyo.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.
Jan. 21-23. Annual meeting at New York, Engineering Societies Building, 29 West 39th St. Secy., W. M. Mackay, 29 West 39th St., New York.

NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION.
Jan. 23-25. Annual meeting at Chicago. Secy., C. R. Richards, Columbia University, N. Y.

THE NEW YORK RAILROAD CLUB will hold its Christmas smoker and social reunion at the Engineering Societies Building, 29 West 39th St., on the evening of Dec. 20.

SOCIETY OF CHEMICAL INDUSTRY (New York Section).—There will be a meeting of the section at the Chemists' Club, 108 West 55th St., on Dec. 20, 8.15 p. m., at which Mr. Maximilian Toch will present a paper on "Photography in the Colors of Nature, with Special Reference to the New Lumiere Process."

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.—At the annual meeting in Chicago a special meeting of engineers and mathematicians is to be held under the joint arrangements of Sections A and D of the Association and the Chicago section of the American Mathematical Society. This will include two sessions to consider subjects as follows: (1) The present status of the teaching of mathematics to students of engineering, both in this country and abroad. (2) What is needed in the teaching of mathematics to students of engineering: (A) What range of subjects; (B) To what extent in the various subjects; (C) By what methods of presentation; (D) What should be the chief aims. The joint sessions will be held in the Ryerson Physical Laboratory, of the University of Chicago.

THE CONCRETE ASSOCIATION OF AMERICA.—This association, which is composed of men who are engaged in developing the correct use of concrete, has recently opened a permanent exhibition of concrete and cement products at the Brunswick Building, Fifth Ave. and 27th St., New York. The primary purpose of this exhibition is to show the architect, the builder and the owner who may have certain prejudices against the use of concrete in any but mass work, that the artistic and scientific treatment of the material has reached such a stage that it is not only safe and economical, but that it can be made beautiful. Particularly is the purpose of the show to demonstrate to the incredulous architect that he can build out of concrete, structures which will suit the most esthetic taste. The exhibit comprises many model buildings and sections of buildings, portions of columns and beams, examples of surface finish and parts of cement laboratories. A permanent secretary is in attendance and will be glad to assist visitors in gaining any information not evident from the exhibits.

ILLUMINATING ENGINEERING SOCIETY.—At a meeting of the New York Section on Dec. 12, Mr. Bassett Jones, Jr., presented a paper on "The Relation of Architectural Principles to Illuminating Engineering Practice." The object of the paper was evidently to correct a condition which too many architects seem to feel is widespread. This was expressed in one early paragraph of the paper:

> The engineer has unfortunately little opportunity of learning to appreciate beautiful things and his limitation in this regard often leads him unduly to accent what he terms "practical considerations." He sometimes forgets that there is an essentially pragmatic purpose at the basis of all true art and that the esthetic emotions are increasingly important as man reaches the higher stages of mental development.

The first two thousand words of the paper formed an elucidation of the nature of esthetic feelings and qualities. However, the portion of the paper on architectural principles, and on the laws of proportion and of ornamentation, was more useful in showing the limitations which architects place on the illumination schemes and which it must be admitted engineers oftentimes disregard.

In this paper such an extreme position was taken in regard to the dictates of the architect that an engineer associated on the design of a structure would have little left to do with the lighting except to compute the amount of the feeble light which the architect would allow and to find the high degree of inefficiency at which the lighting was attained. In spite of the great length of the paper rather too few suggestions were made as to the methods to be pursued, to agree with the architects' ideas of fitness.

The discussion afforded several architects an opportunity to express their opinions of the engineer's usefulness in the field of art. It was to be expected that some would further criticise the work of engineers but it seemed like a descent to mere vituperation when it was stated, for instance, that an engineer's ideas of beauty were best embodied in ornate glittering stamped spun brass in grotesque form and arrangement.

That some architects hold a more reasonable view of the engineer's ability and usefulness was shown in the discussion by Mr. S. W. Jones, Architect, New York City. He divided the common work of architects and engineers into two classes: (1) those modern structures in which it is always necessary to consider their utility and subordinate the historical treatment; (2) structures in which the historical treatment is predominant and in which the desired utility can always be attained without any sacrifice or distortion of architectural effect. In the first class the engineer's requirements must stand, in the latter the architect's views must prevail.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.—On Dec. 13 Mr. H. H. Walt, Assistant Electrical Engineer, Western Electric Co., in a paper entitled "An Exhaust Steam Turbine Plant," described a power installation at the mill of the Wisconsin Steel Co., South Chicago, Ill. Here a low-pressure Rateau impulse turbine utilizes the exhaust from a reversible rolling mill engine. This engine when running showed an average of 1,010 I. HP. and a steam consumption of 54 lbs. per average I. HP. during actual running. This engine takes steam for nearly full stroke when starting the passes and runs on very light load the rest of the time. The HP. and the torque are very high on starting.

The steam passes from this primary engine to a receiver, thence to an accumulator, and from there to the turbine and condenser. The receiver consists of a vertical tank with numerous baffle plates and is provided with oil and water drains. The accumulator consists of a large horizontal cylindrical tank divided by a diaphragm into two decks, in each of which are a number of perforated steam pipes immersed in water. The steam is sprayed through the mass of the water and gives up some of its heat to the water, depending on the condensation. Should the steam supply drop the pressure in the accumulator must drop, and under such a reduction the water at a temperature corresponding to the former pressure gives off steam. The normal operation is at about 2 lbs. above atmospheric pressure. The size of the accumulator is such that the turbine will operate for some seven minutes before live steam is admitted to the accumulator.

During three months in which the steel plant was running at nearly full capacity the turbine delivered an average of 51% of the total KW.-hrs. possible at full load for this time and at a cost of about 0.3 of a cent per KW.-hr.

The discussions of the evening turned on the paper by Mr. W. S. Finlay, Jr., Assistant Engineer to the Superintendent of Motive Power, Interborough Rapid Transit Co., New York City, on "The Ratio of Heating Surface to Grate Surface as a Factor in Power Plant Design." The theory advanced was, in brief, that great increase in boiler capacity can be obtained, without material sacrifice in efficiency, if there is a proportional increase in grate surface. It is considered possible that in increasing the grate surface that the conditions for combustion, heat distribution and transfer could be much improved. Features of a change made at the 59th St. plant of the Interborough Rapid Transit Co., New York City, was outlined as following this theory. Under the mud drum of each of 18 water-tube boilers a second stoker was installed. The boiler capacity was increased 71% with no loss in economy. At 80% increased straining capacity the boiler efficiency was lowered only 2 or 3%. Mr. Finlay claimed that by such increase in grate surface the first cost of a plant would be cut down 19 or 20% and that total operating expenses would be reduced from 5 to 10%, depending on the load factor of the plant.

The discussions were in general quite unfavorable to the theory. Prof. C. E. Lucke, of Columbia University, in analyzing the results of the tests at the Interborough station stated that some conditions not stated in the paper might reverse the cost reductions quoted as an instance it was stated that an appreciably higher flue temperature under furnace conditions outlined would materially increase expenses.

Mr. J. B. Sparrow, Chief Engineer, New York Edison Co., stated that the data in Mr. Finlay's paper appeared to show a fair performance under single stoker operation and a poor one with the double stoker arrangement. At the Edison plant a greatly increased rate of fuel combustion had been maintained with increased boiler capacity and with little decrease in combined efficiency of the boiler if the operation was maintained merely at peak loads.